Recovery Plan for the Northern Spotted Owl - DRAFT

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island Territories under U.S. administration.

Recovery Plan for the Northern Spotted Owl - DRAFT

April, 1992

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This recovery plan is not intended to provide precise details on all aspects of northern spotted owl management. The recovery plan outlines steps necessary to bring about recovery of the species. The recovery plan is not a "decision document" as defined by the National Environmental Policy Act (NEPA). It does not allocate resources on public lands. The implementation of the recovery plan is the responsibility of federal and state management agencies in areas where the species occurs. Implementation is done through incorporation of appropriate portions of the recovery plan in agency decision documents such as forest plans, park management plans, and state game management plans. Such documents are then subject to the NEPA process of public review and selection of alternatives.

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Executive Summary of the Northern Spotted Owl Recovery Plan

Introduction

A recovery plan is called for by the Endangered Species Act to guide the management actions needed to bring a threatened or endangered species to a condition in which it no longer needs special protection of the act. The northern spotted owl (also referred to in the recovery plan as the spotted owl and the owl) was placed on the list of threatened species in June 1990. Since February 1991, a Recovery Team appointed by Secretary of the Interior Manuel Lujan Jr. has been formulating a recovery plan for the spotted owl. This report presents a draft recovery plan for the northern spotted owl for review and comment by the public and government agencies.

The northern spotted owl draft recovery plan provides a comprehensive basis for management actions to be undertaken by forest landowners and wildlife agencies to alleviate conditions threatening the species. Primary actions will be taken by federal land management agencies in the Pacific Northwest — the U.S. Forest Service, the U.S. Bureau of Land Management, and the National Park Service. The U.S. Fish and Wildlife Service will oversee implementation of the plan through its authorities under the Endangered Species Act.

State forest management and wildlife agencies in Oregon, Washington, and California also will take actions that contribute to recovery under the plan. These state agencies have an important role in managing state forests and in regulating forest practices on private land within their jurisdiction. Contributions from habitat on Indian lands also were considered in formulating the draft plan.

The draft recovery plan was developed following review of the scientific data from previous plans for the spotted owl, particularly the conservation strategy designed by the Interagency Scientific Committee (ISC) (Thomas et al. 1990), and by analyzing the most recent data available on owl populations and their habitat. This biological information was the basis for designing measures to achieve recovery.

Secretary of the Interior Lujan also asked that the Recovery Team consider other species and economic effects to the extent allowed by law. The Recovery Team made a substantial effort to determine the status and location of other species that could benefit from actions similar to those needed for owl recovery. Measures that would contribute to recovery of the owl, while also helping other species, were favored in decisions leading to the draft recovery plan.

Previous studies show that protection of sufficient habitat for a viable spotted owl population has substantial economic and social costs because of the reduction in timber harvests. The Recovery Team recognized that, under the Endangered Species Act, it could not consider measures short of achieving recovery for the northern spotted owl, even though such measures might cause significantly less economic and social losses. Instead, the Recovery Team looked for ways to achieve recovery that would cause less reduction in timber harvest and fewer job losses in the timber industry.

Recovery Objective

The objective of the draft recovery plan is to remove the northern spotted owl from the list of threatened species.

The Draft Recovery Plan

The northern spotted owl draft recovery plan has seven key elements:

1. A recovery objective and a set of criteria for determining whether conditions exist that would allow the northern spotted owl to be removed from the list of threatened species.

2. A network of designated conservation areas on federal forestlands, with each area designed to protect owl habitat sufficient to support a number of breeding pairs of owls.

3. A set of guidelines that govern management activities on federal forestlands in designated conservation areas.

4. A set of guidelines that govern management activities on federal forestlands outside of designated conservation areas.

5. A set of suggestions for contributions from nonfederal forestlands to support spotted owl populations.

6. A monitoring and research program that will provide new information on spotted owls and their habitat, and develop and test management techniques for promoting and maintaining owl habitat while allowing appropriate forest management.

7. Implementation mechanisms that provide oversight and coordination, relying primarily on existing authorities and forest management planning procedures.

Each of these elements is described briefly, followed by a discussion of the scientific basis for the plan and of the economic and social considerations built into the plan.

Delisting Criteria

The primary threat to the northern spotted owl leading to its designation as a threatened species is the reduction and fragmentation of its habitat in forests in Washington, Oregon, and northern California. Northern spotted owls use old-growth forests and other forests with similar characteristics for nesting, breeding, and rearing young. As timber harvesting has proceeded in the Pacific Northwest, the amount of habitat suitable for spotted owls has declined and remaining habitat areas have become smaller and more isolated from each other, particularly during the last 50 years. As a result, the population of spotted owls declined, in some areas rather sharply.

The objective of the draft recovery plan is to reduce the threats to the spotted owl so that it can be removed from the list of threatened species anywhere in its range. The decision to remove the spotted owl from the list of threatened species can be made on an incremental basis for individual areas, called provinces, or for groups of provinces. The range of the spotted owl has been divided into 11 provinces.

Four criteria must be met before delisting is considered: (1) A scientifically credible plan for monitoring owl populations and owl habitat must have been in effect for at least 8 years; (2) the population must have been stable or increasing, as indicated by both density and demographic estimates, for at least 8 years; (3) regulatory mechanisms or land management commitments must have been implemented that provide for adequate protection of breeding, foraging, and dispersal habitat, and (4) analyses must indicate that the population in unlikely to need protection under the Endangered Species Act during the foreseeable future. The draft recovery plan emphasizes that all of these criteria must be satisfied before delisting is considered.

Designated Conservation Areas

As the primary means for achieving recovery, the draft plan recommends establishing 196 designated conservation areas (DCAs) to provide approximately 7.5 million acres of federal forestland as the primary habitat for the northern spotted owl population. These DCAs include approximately 48 percent of the total remaining spotted owl nesting, roosting, and foraging habitat on federal lands (Figure ES.1.). The largest DCAs are designed to support a population of 20 or more pairs of owls in habitat conditions that allow successful breeding and rearing of young. They are located to allow owls to disperse from one DCA to another. Each DCA contains areas of currently existing owl habitat combined with areas of younger forests. These younger stands will be protected so they can mature into owl habitat. The DCAs contain approximately 1,180 known owl pairs on federal lands. This represents about 48 percent of the total pairs currently known on all federal lands (Figure ES.2.). When the DCAs become fully developed owl habitat, they will support a population of approximately 2,320 pairs of owls.

DCAs are located to take advantage of other forestland containing owl habitat that will not be harvested or will be harvested in a manner that does not reduce habitat value. Such areas include parks, wilderness areas, and certain administratively reserved areas. DCAs also are located in a pattern to reduce the risk to the owl population from natural threats such as fire, disease, and insects.

Management Rules for Designated Conservation Areas

The draft recovery plan recommends that activities on federal lands within the DCAs be focused on improving habitat conditions for spotted owls.

The following specific management rules for federal lands in DCAs are recommended.

1. No timber harvest is allowed in habitat suitable for northern spotted owls.

2. Silvicultural practices, such as thinning, will be used to promote rapid development of owl habitat in those areas that currently do not provide habitat suitable for owls.

3. Salvage of trees in stands significantly affected by fire, wind, insects, or diseases may occur but will be limited to safeguard owl habitat.

4. Management activities designed to reduce the risk of large-scale fire or insect infestation are limited to those needed to assure the continued existence of owl habitat within the DCA.

5. The recovery plan recommends that federal lands inside DCAs, with the exception of wilderness areas and national parks, be designated as critical habitat.

6. It also recommends that a management plan be prepared for each DCA before management activities are implemented.

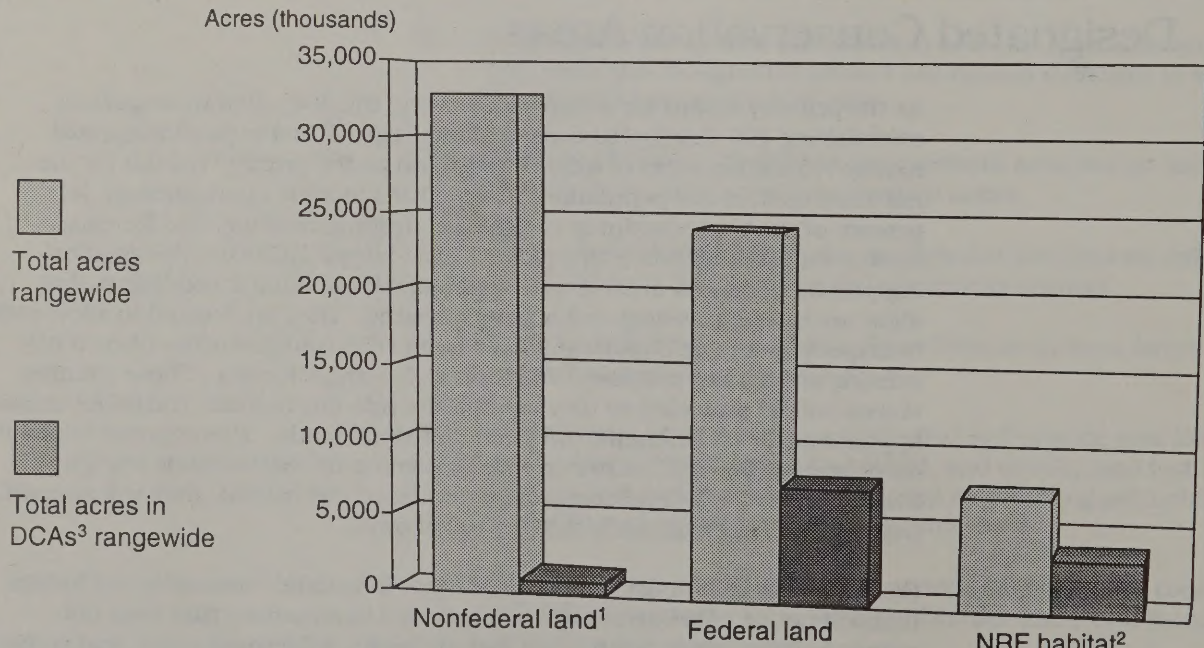


Figure ES.1. Total acres in the range of the northern spotted owl and in DCAs[3] within the range.

[1]No commitments are implied by inclusion of nonfederal land within DCA boundaries. Management of these lands is discussed in section III.C.4.

[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

[3]DCA = designated conservation area.

Management Guidelines for Federal Forestlands Outside Designated Conservation Areas

The draft recovery plan recommends guidelines for the maintenance of sufficient habitat conditions on federal lands outside DCAs to allow dispersal of owls among DCAs. Movement among DCAs is necessary to maintain population levels and prevent genetic deterioration of the population. These guidelines also contain several recommendations for supplementing the DCA network in specific parts of the owl's range where conditions currently do not allow full implementation of the DCA network guidelines. This would be done by providing habitat for additional owl pairs and territorial single owls outside DCAs. In some areas, the draft recovery plan recommends management of these areas to reduce the risk of fire and insect damage. In total, these matrix areas in combination with the DCAs will provide for approximately 1,300 currently known pairs of owls on federal lands. This represents about 53 percent of all pairs currently known to occur on federal lands.

Suggestions for Management of Nonfederal Forestlands

The draft recovery plan relies first on federal lands for recovery of northern spotted owls. However, it also recognizes the role of nonfederal lands in recovery, particularly in areas where federal lands are not adequate to fully achieve the recovery objective. The recovery plan recommends specific contributions from nonfederal lands which will complement federal efforts. These recommendations reflect the varied conditions within individual provinces, the authorities of the three states involved, and the potential for enhanced cooperation with the private sector. They provide a framework for development and implementation of creative efforts to help achieve recovery.

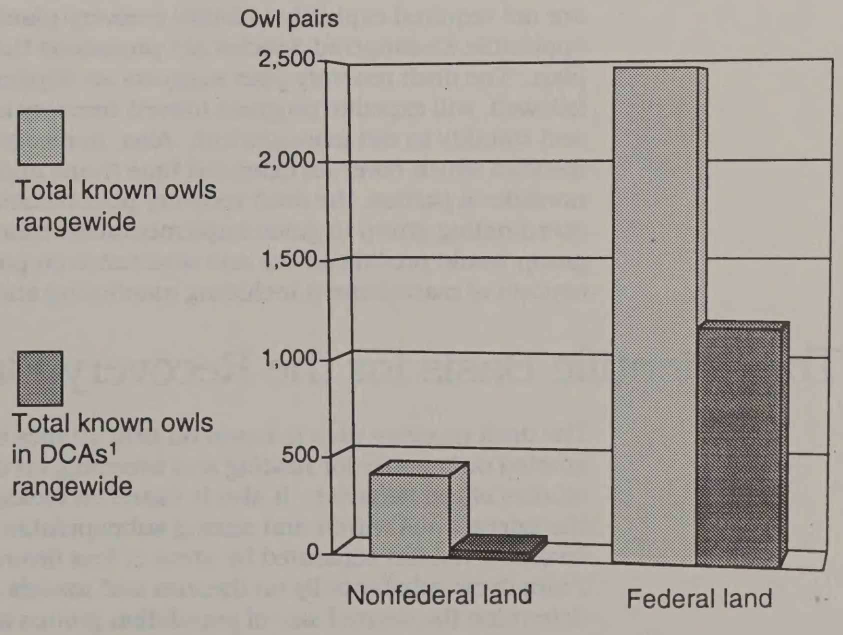


Figure ES.2. Total known owl pairs rangewide and in DCAs.
[1]DCA = designated conservation area.

Monitoring and Research Program

The draft recovery plan is based on extensive scientific data on northern spotted owls. This information gives the Recovery Team reasonable assurance that implementation of the draft plan will result in recovery of the species. However, increased knowledge of owls and their habitat will provide opportunities to refine and improve the plan. Consequently, the draft recovery plan recommends a comprehensive monitoring, research, and adaptive management program. The program has two objectives:

1) It will help produce information to assist in refining management guidance and practices to promote recovery and, to the extent feasible, achieve greater economic efficiency and effectiveness. The program will include assessments of how implementation techniques are applied and the results they achieve.

2) It will provide documentation necessary to consider delisting the owl in part or all of its range.

Information derived from the monitoring and research program eventually may result in significant changes in the Recovery Team's recommendations. The Recovery Team has a long-term goal to move from a landscape composed of protected areas and matrix toward a landscape where conditions provide a more continuous distribution of owls. Results from monitoring and research may support such a change. In any case, the delisting criteria still would be appropriate even if specific recommendations changed.

Implementation Mechanisms

Recovery plans are not self-implementing under the Endangered Species Act. Instead, they are used by federal agencies as a guide to refine management plans, procedures, and strategies so that on-the-ground operations help achieve recovery as it is defined in the draft recovery plan. Nonfederal parties are not required explicitly to follow recovery plans. However, they must follow applicable Endangered Species Act provisions that are reflected in the recovery plan. The draft recovery plan suggests an implementation schedule which, if followed, will expedite progress toward recovery and provide increased certainty and stability in owl management. Also, in recognition that actions are recommended which cover an extended time frame and involve federal and nonfederal parties, the draft recovery plan recommends establishment of a coordinating group to guide implementation efforts over the long term. The group would provide advice and assistance on policies, plans, and other aspects of management including monitoring and research.

The Scientific Basis for the Recovery Plan

The draft recovery plan is based on field studies of the habitat conditions that spotted owls prefer for nesting and breeding, on demographic studies, and on studies of owl behavior. It also is based on biological principles that describe the interactions within and among subpopulations that depend on areas of favorable habitat separated by areas of less favorable conditions. The Recovery Team drew substantially on theories and models of population dynamics to determine the desired size of population groups and the overall population.

The draft recovery plan also is based on silvicultural studies of the growth of forests under natural conditions and human management. Silvicultural models were used to study the opportunities for promoting more rapid development of suitable habitat conditions by appropriate management in younger stands.

Consideration of Economic and Social Effects

The draft recovery plan was designed to reduce economic and social costs without undermining recovery of the spotted owl. For example, it allows forest management within DCAs in areas that are unsuitable for owls if that management is designed to promote the development of suitable owl habitat. Some of that management may provide commercial wood products. It also uses much habitat already set aside as not suitable for timber harvest. The plan also provides programs and procedures to reduce the costs of its implementation. However, the cost of the plan still will be significant, and disruption will be experienced by individuals and communities when restrictions on timber harvesting cause unemployment.

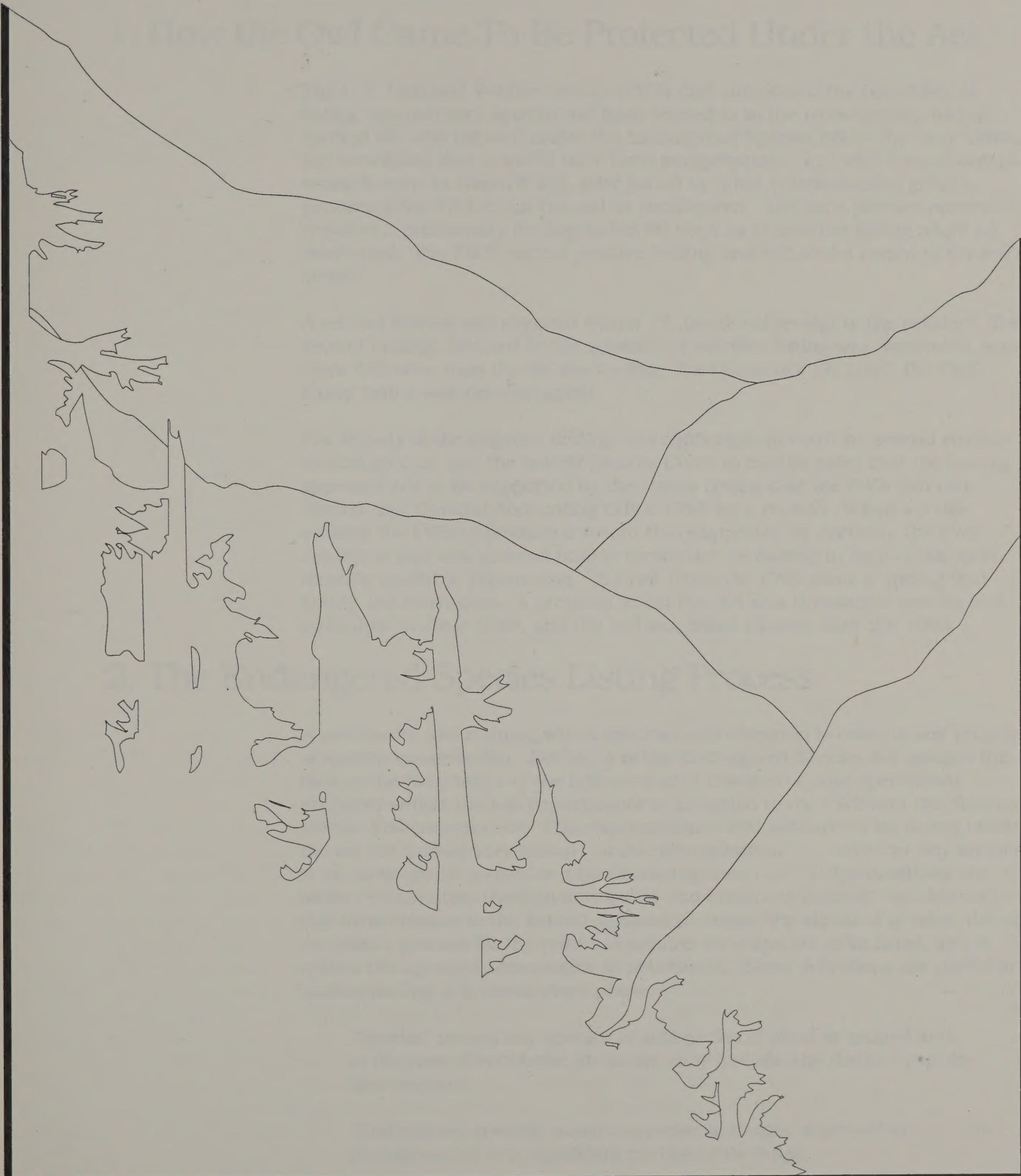
Implementation of the draft recovery plan is estimated to reduce employment in the Pacific Northwest timber industry by about 18,900 jobs, compared to the employment that would have been expected in 1995 with no protection of the spotted owl. Jobs in related sectors also will be reduced by about 13,200. Lost or reduced wages are estimated to be about $1.4 billion during the coming 2 decades. The value of the foregone timber harvest is estimated to be $470 million per year. This will cause a net reduction of about $328 million per year in U.S. Treasury funds and $100 million per year in county receipts. Private assets, such as mills and homes, also will be reduced in value.

Conclusion

The conservation of northern spotted owls is a difficult public policy issue. It is important to achieve recovery in a way that is appropriate under the Endangered Species Act, yet also managerially and economically efficient. The draft recovery plan provides a realistic basis for meeting this objective. Consequently, it should meet owl needs and provide greater stability in resource management than now exists. This will set a precedent for constructively resolving conflicts between conservation and development of natural resources.

Chapter I

Introduction



I.

A. The Northern Spotted Owl and the Endangered Species Act

1. How the Owl Came To Be Protected Under the Act

The U.S. Fish and Wildlife Service (FWS) first considered the possibility of listing the northern spotted owl (also refered to in the recovery plan as the spotted owl and the owl) under the Endangered Species Act in the early 1980s, but concluded that it would have been inappropriate. In 1987, a small organization known as GreenWorld, later joined by other environmental groups, petitioned the FWS to list the owl as endangered. The act's petition provisions required a preliminary finding within 90 days as to whether listing might be warranted. The FWS made a positive finding and initiated a review of the owl's status.

A second finding was required within 12 months of receipt of the petition. The second finding, directed at the question of whether listing was warranted, was more definitive than the 90-day finding. On December 17, 1987, the FWS found listing was not warranted.

The legality of the negative finding was challenged in court by several environmental groups, and the federal District Court in Seattle ruled that the finding appeared not to be supported by the status review that the FWS had conducted (see General Accounting Office 1989 for a review). When a judge ordered the FWS to produce a record that supported its decision, the FWS requested and was granted time to reconsider its finding in light of the most recently available information. In April 1989, the FWS made a finding that listing was warranted. A proposal to list the owl as a threatened species was published in June 1989, and the owl was listed effective July 23, 1990.

2. The Endangered Species Listing Process

A process for ascertaining which species need attention is basic to any program of species conservation. Section 4 of the Endangered Species Act assigns this task to the Secretaries of the Interior and of Commerce, and operational authority within the two departments is delegated to the FWS and the National Marine Fisheries Service. The responsibilities and authorities for listing under the act are framed very broadly as the determination ". . . whether any species is an endangered species or a threatened species . . .." Determinations are made by regulation through a proposal-and-comment process. In addition to this broad charge to the federal agencies to assess the status of species, the act provides a process for the public to petition for a species to be listed, and it makes the agencies accountable to petitioners. Some definitions are useful in understanding this assessment phase.

> "Species" means any species or subspecies of plant or animal and, in the case of vertebrate life forms, may include any distinct population segment.
>
> "Endangered species" means a species in danger of extinction throughout all or a significant portion of its range.

> "Threatened species" means a species likely to become endangered in the foreseeable future throughout all or a significant portion of its range.

The Endangered Species Act requires that listing decisions be made "solely on the basis of the best scientific and commercial data . . .." In this context, "commercial data" refers solely to information regarding trade in a species or products derived from it, and does not allow the probable economic consequences to affect a decision regarding a species' listing.

3. Critical Habitat Designation

The Endangered Species Act also directs the agencies to propose critical habitat "to the maximum extent prudent and determinable." Once again, the act's definitions are important.

> "Critical habitats" are specific areas within the geographical area occupied by a species at the time of listing on which are found those physical or biological features (1) essential to the conservation of the species; (2) which may require special management considerations or protection; and (3) specific areas outside the area occupied by the species upon a determination that such areas are essential to its conservation.

> "Conservation" means the use of all methods and procedures necessary to bring a species to the point at which the protective measures of the act are no longer necessary. Conservation is the process or means of achieving recovery. It is reasonable for the designation of critical habitat areas "essential to the conservation of the species" to consider the habitat needs identified in a recovery plan.

Designation of critical habitat is considered to be prudent when it would be of conservation benefit to the species for which it is designated. Critical habitat is determinable if sufficient information is available to adequately delineate the area or areas that should be included in the designation.

The act also requires an examination of the economic and other relevant impacts of the designation of critical habitat, and allows areas to be excluded from critical habitat if the benefits of exclusion outweigh the benefits of inclusion, unless exclusion would lead to the extinction of the species.

In the proposed and final listing of the northern spotted owl, the FWS deferred designation of critical habitat as "not determinable." Critical habitat must be designated to the maximum extent prudent and determinable at the time a species is listed. If critical habitat is not determinable at listing, the act allows an additional year beyond the one in which listing must progress from proposed to final. At the end of the second year, critical habitat must be designated to the maximum extent prudent. In further consideration of the case that challenged the FWS's original petition finding, the court did not accept the FWS's argument that critical habitat for the owl was not determinable, and ordered the FWS to publish a proposal to designate critical habitat by April 29, 1991. A proposal for 11.6 million acres of critical habitat was published on May 6, 1991. A revised proposal that reduced the area to about 8.2 million acres, principally by excluding private, Indian, and state lands, was published on August 3, 1991, and a final designation of 6.9 million acres was issued on January 15, 1992.

4. Recovery Plans

The Endangered Species Act calls for the preparation of recovery plans for listed species that are likely to benefit from the effort, and authorizes the Secretary of the Interior to appoint recovery teams. A recovery plan must establish recovery goals and objectives, describe site-specific management actions recommended to achieve those goals, and estimate the time and cost required for recovery. A recovery plan is not self-implementing, but presents a set of recommendations endorsed by an approving official representing the Department of the Interior.

The Secretary appointed an interdisciplinary Northern Spotted Owl Recovery Team in February 1991. The Secretary's directive to the team (see Appendix K) called for a biologically credible plan. The Secretary further directed that the plan should, consistent with its legal mandate, "address concerns such as: potential community and regionwide economic and social impacts; fiscal implications at the local, state and federal levels; compatibility with other legal mandates; effects on other threatened and endangered species and those species which might be listed in the future; and broader, ecosystem-related considerations."

The Northern Spotted Owl Recovery Team includes members of federal agencies, academic scientists, and representatives from the governors' offices in California, Oregon, and Washington. The Recovery Team held meetings each month from March to September 1991 that were open to the public and then met in closed session while it developed final options and recommendations for the Secretary's review.

At its first meeting, the Recovery Team established standing committees to address particular aspects of preparing the recovery plan; members of the committees are shown in Appendix K. Committees were established for owl biology, planning and implementation, forest ecology and management, other species, and economics. An executive committee also was formed whose membership included the Recovery Team chairman, team coordinator, and all committee chairpersons. The committees gathered information and provided evaluations in their respective subject areas for presentation to and action by the full Recovery Team.

The Recovery Team held numerous meetings as a full team and in smaller committees working on specific matters. Members visited a wide variety of owl habitats and forests in the three states, including lands in the Mt. Hood and Six Rivers National Forests, Olympic National Park, the Bureau of Land Management Eugene District, the Yakima Indian Reservation, Oregon's Tillamook State Forest, and several privately owned commercial forests.

The Recovery Team's mandate and its inclusion of some members with backgrounds in areas other than the biological sciences make it unusual among recovery teams. This structure enables the Recovery Team to consider and, as appropriate, to reduce the cost of recovery. It is also significant that Congress agreed to Conference Report language accompanying the 1992 Interior and Related Agencies appropriation bill encouraging the Recovery Team to consider the social and economic impacts of the recovery plan.

B. The Interagency Scientific Committee

While the proposal to list the northern spotted owl was pending, the four principal federal agencies involved in management of the owl (Forest Service, Bureau of Land Management, Fish and Wildlife Service, National Park Service) commissioned an Interagency Scientific Committee (ISC) to develop a conservation strategy for the owl. The committee delivered its product in April 1990 in the form of a strategy organized around the establishment of habitat conservation areas (HCAs) throughout the range of the owl, including an adaptive management approach (Thomas et al. 1990). The ISC strategy represented a significant gathering and synthesis of information on the biology and conservation of the owl and provided a point of departure for much of what subsequently has occurred regarding owl conservation. The ISC report concluded that at that time management strategies were inadequate to ensure the owl's viability. The ISC believed its strategy, ". . . if faithfully implemented, has a high probability of retaining a viable, well-distributed population of northern spotted owls over the next 100 years," (Thomas et al. 1990:4).

In many respects the task of the Recovery Team is similar to that of the ISC. There are, however, several significant differences. The most fundamental differences concern the frames of reference of the two groups. When the ISC was formed and prepared its strategy, the owl had not been listed as threatened and was not subject to protection under the Endangered Species Act. The strategy was commissioned by federal agencies, and members of the core committee of the ISC were federal employees. The committee had no obligation to and did not attempt to articulate its strategy in terms of the owl's recovery from threatened status.

The Recovery Team began its work after the owl had been listed. Protective measures had taken effect and were available as tools for conservation. The Recovery Team, appointed by the Secretary of the Interior, includes in its core membership academic scientists and representatives of the governors of the three affected states. Direct participation at this level by the states gave the Recovery Team a greater opportunity to address the entire range of the owl and management of owls on nonfederal lands than was afforded the ISC. Perhaps most important, a recovery team must, if possible, develop goals for the recovery of a species to the point at which it may be removed from the endangered or threatened list and also must describe criteria by which achievement of these goals can be recognized.

Similarities between the ISC strategy and this recovery plan arise from their common foundation in the biology of the owl and reliance on available management tools and principles of conservation biology. Differences between the two reflect the differing composition and charters of the groups that prepared them.

C. The Biological Basis of the Plan

The conservation measures in the recovery plan reflect general biological principles and specific knowledge concerning the biology of the northern spotted owl. In large part, the plan borrows from and builds upon the concepts and information presented in the ISC strategy. The following principles provide a biological basis for the plan:

- The risk of local or widespread extirpation will be reduced by managing for owls across their entire range and in the variety of ecological conditions within that range.

- Emphasis should be placed on management for clusters, or local population centers, of owls habitat blocks, rather than for individual pairs.

- Habitat conditions and spacing among local populations should provide free movement of owls to allow a metapopulation structure to operate.

For the owl, these principles result in recommendations for a) a network of designated conservation areas (DCAs) sufficiently large when possible to support 20 pairs of owls each, b) management within DCAs to maintain or increase suitable habitat for owls, and c) management to allow owls to move among DCAs. The size and arrangement of DCAs are based on information about the size of territories established by pairs of owls and the ability of owls to disperse. Knowledge of habitat characteristics needed to support owls provided a basis for recommending management of forestlands to support recovery. Throughout the plan, recommendations are tailored to locally specific information. Organization of recovery around multipair habitat areas is particularly appropriate for this species because of knowledge of its behavior, which includes significant inter-pair interaction.

In addition to owl conservation, the recovery plan considers the biology and conservation needs of other species that occur within the range of the owl. The recovery plan incorporates elements to benefit other species and general ecosystem values when doing so adds little or no additional cost while conserving the owl.

D. The Means of Achieving Recovery

The recovery plan recommends an approach to owl recovery that involves federal, state, and private sectors. The underlying strategy is interactive, and accordingly, recommends management objectives and practices consistent with the various implementation mechanisms available among these sectors. The Recovery Team believes this approach is the most efficient and effective means to achieve recovery. At the same time, however, the Recovery Team understands that the statutory mandates of the recovery planning process and the Endangered Species Act impose different requirements on land managers and owners. Accordingly, the recommendations place strong emphasis on the need for appropriate federal land management as a basis for recovery. As the plan is implemented, achieving or exceeding recommended state and private commitments in some physiographic provinces may hasten recovery, and perhaps ultimately enable greater flexibility in federal management than the plan now envisions. In other provinces, however, particularly where obstacles to recovery are acute, flexibility is not likely to be possible in the immediate future.

E. Sources of Information

Both published and unpublished documents (unpublished documents are commonly referred to as "grey literature") have been used as references in this plan. Grey literature has not been subjected to formal, rigorous peer review, and thus its acceptability among scientists as a source of information from which inference can be drawn is low. Likewise, published documents vary in their utility as sources of information. In general, popular articles (e.g., those in newspapers and magazines) have the lowest value as sources of unbiased information. With one exception, none is cited in this review. Privately pub-

lished works and many government documents are not usually formally reviewed, and often are referred to as grey literature. Peer-reviewed scientific journals, symposia, and books form the backbone of scientific literature. While peer review cannot, in most cases, assure the credibility of raw data, it does assure the reader that the information has been subjected to rigorous scrutiny of its methods, analysis, logic, and the appropriateness of an author's inferences and conclusions given the quality and amount of data and the analytical tools used to evaluate the data. In the case of the northern spotted owl, much of the available information is found only in grey literature. Grey literature frequently has been used in this document because it often represents the very latest field data. In addition, to categorically reject grey literature would result in a virtual absence of information derived from the timber industry. Use of such information should result in a more informative review and a stronger recovery plan.

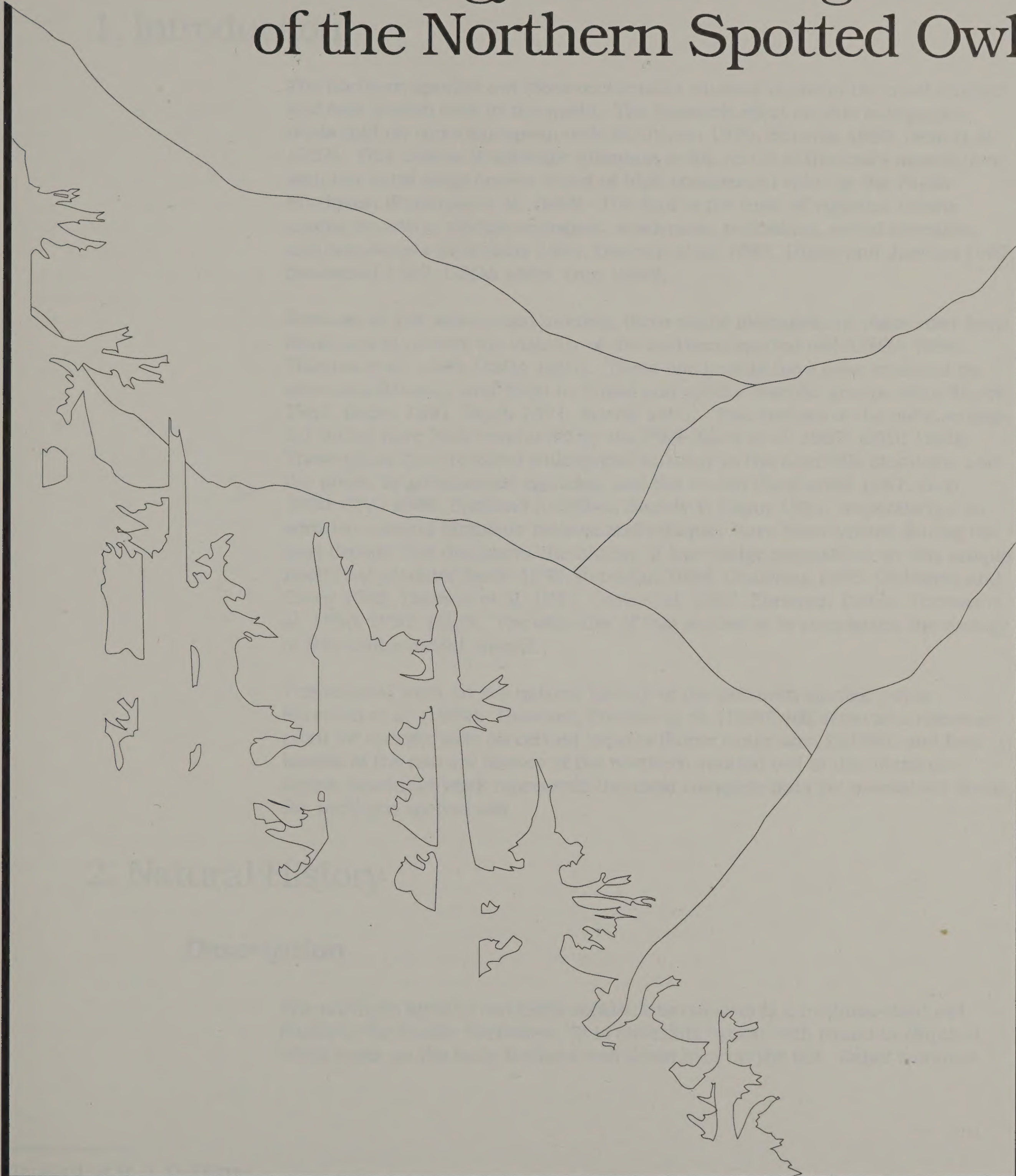
F. Acknowledgments

The Northern Spotted Owl Recovery Team has been assisted in its work by a legion of able cooperators. Many of these people volunteered their time and efforts in excess of what anyone could have plausibly expected, and have endured schedules and deadlines that can only be described as unreasonable. The list below is undoubtedly incomplete, and the Recovery Team regrets any omissions. To all named and any unnamed collaborators, we express our gratitude; we could not have completed our work without their contributions. James K. Agee, David Allen, David Anderson, Brad Andres, Keith Aubry, Phil Aust, Robert W. Baker, Allison Banks, Timothy A. Barnes, Joseph Beatty, Gary Benson, Marty Berbach, Bill Beyers, Monte Bickford, Bruce Bingham, Kevin Birch, Helen Birss, Andrew Blaustein, Kathryn Boula, Nancy Brooks, Charlie Brown, Ken Burnham, Bruce Bury, Andrew Carey, Jill Carroll, John Charbonneau, Steve Corn, Eric Cummins, Tom Cyra, Larry Davis, William F. Delaney, Velma Delp, Nicholas Dennis, Randy Dettmers, Lowell Diller, Aimee Dour, James Eby, Ed Ehlers, Rich Everett, Robert A. Ewing, Lee Folliard, Eric Forsman, Louise Fortmann, Alan Franklin, Terrence Frest, Florissa Fuentes, Bob Gara, Keith Gilless, Brian Greber, Jeff Grenier, John H. Grobe, Tom Hamer, Michael Hamel, Melissa Hamel, Jeff Hannum, Mark Harmon, Connie Harrington, Michael Hay, Mauragrace Healey, Lorin Hicks, Patrick Higgins, Jerry Hoyer, Robert J. Hrubes, Mark Huff, Larry Irwin, Frank Isaacs, Kirk Jobeson, K. Norman Johnson, Rebecca Johnson, Connie Kahn, Boone Kaufmann, Jon Kennedy, Steve Kerns, Walt Knapp, William LaHaye, Jack Lattin, Robert G. Lee, George Leitner, Gary Lettman, Rob Lewis, Joe Lint, Bruce Lippke, Dan Luoma, Mike Lunn, Tom Lynch, Kathy Majors, Bruce Marcot, Sandy Martin, Bill McComb, Kevin McKelvey, William McKillop, Walter J. Mead, Chuck Meslow, Joe Meyer, Nanette Miller, Christine Moen, Andrew Moldenke, Jeff Morrell, Peter Morrison, Robert Motroni, Barry Mulder, Ed Murphy, Gil Murray, Jim Neely, Susan Nelson, Bill Nietro, Barry Noon, Theron Odell, Kathy O'Halloran, Chad Oliver, Tom Owen, Dave Perry, Rick Peterson, Malcolm Pious, Ann Potter, Terry Raettig, Martin Raphael, Richard Reynolds, Jo Ellen Richards, Paul Roush, Frank Ryals, Bob Saunders, Mel Schamberger, Steve Self, Mike Skinner, David Solis, Paul Sommers, Tom Spies, Mike Srago, Argon Steel, John Steffenson, Dave Stere, Robert Storm, John Teply, Steve Tesch, Jack Ward Thomas, Dale Thornburgh, David Thorud, Melvie Uhland, Jerry Verner, Frank Wagner, Paul Warner, Bill Watterson, Phil Weatherspoon, Thomas Williams, Wendell Wilson, George Wyatt, Cindy Zabel, and John Zasada.

No project like this one comes to fruition without exacting a toll on the participants' personal support groups of family and friends. We appreciate the indulgence of those closest to us, who have put up with our frequent physical and mental absences during the preparation of this recovery plan.

Chapter II

Biology and Management of the Northern Spotted Owl



II.

A. Natural History of the Northern Spotted Owl*

1. Introduction

The northern spotted owl (*Strix occidentalis caurina*) is one of the most studied and best known owls in the world. The research effort on this subspecies rivals that on some European owls (Southern 1970, Saurola 1989, Nero et al. 1987). This degree of scientific attention is the result of this owl's association with late seral stage conifer forest of high commercial value in the Pacific Northwest (Forsman et al. 1984). The bird is the topic of vigorous debate among foresters, wildlife ecologists, academics, politicians, social scientists, and economists (Heinrichs 1984, Dawson et al. 1987, Dixon and Juelson 1987, Simberloff 1987, USDA 1988, Gup 1990).

Because of this widespread interest, three major management plans have been developed to protect the viability of the northern spotted owl (USDA 1988, Thomas et al. 1990, USDA 1991). These documents have been reviewed by scientists (Murphy and Noon In Press) and special interest groups alike (Boyce 1987, Green 1991, Reich 1991, Sheriff 1991). Two reviews of the owl's ecological status have been conducted by the FWS (Gore et al. 1987; USDI 1990). These plans have received widespread scrutiny in the scientific literature, and the press, by government agencies, and the courts (Simberloff 1987, Gup 1990, GAO 1989, Portland Audubon Society v. Lujan 1991, respectively). In addition, several literature reviews and critiques have been written during the past decade that document the history of knowledge acquisition on this unique nocturnal predator (Solis 1980, Forsman 1984, Gutiérrez 1985, Gutiérrez and Carey 1985, Dawson et al. 1987, Gore et al. 1987, Forsman 1988a, Thomas et al. 1990, USDI 1990). The objective of this section is to summarize the ecology of this controversial animal.

The seminal work on the natural history of the northern spotted owl is Forsman et al. (1984). However, Thomas et al. (1990) will serve as a reference point for specific data on certain aspects (home range size, habitat, and food habits) of the natural history of the northern spotted owl in this literature review since that work represents the most complete data yet assembled about the northern spotted owl.

2. Natural History

Description

The northern spotted owl (*Strix occidentalis caurina*) is a medium-sized owl found in the Pacific Northwest. It is chocolate brown with round to elliptical white spots on the body feathers and white bars on the tail. Other common

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distinguishing features are its dark eyes surrounded by tawny facial disks. Males and females are not easily distinguishable by plumage characters, although Barrows et al. (1982) suggested that the sex of spotted owls can be determined from the number of tail bars. Moen et al. (1991) reported that the tail-bar technique is unreliable for sex determination. However, a spotted owl's sex is recognized readily by voice (Forsman et al. 1984; see voice description under Behavior) and size (Forsman et al. 1984, Blakesley et al. 1990). Spotted owls, and owls in general, show reversed sexual dimorphism: females are larger than males (Blakesley et al. 1990:323). This reversed sexual dimorphism exists in all commonly measured physical features, but body mass is the single best physical predictor of sex in this owl (Blakesley et al. 1990:323).

Plumage characteristics can be used to distinguish among several age classes of spotted owls. Juvenile spotted owls (ages 1 day to approximately 5 months) are distinguished by visible down feathers (Forsman 1981). The proportion of down feathers decreases with age. Subadult birds are distinguished by the presence of adult plumage and white-tipped, pointed tail feathers (Forsman 1981). In northern spotted owls, two subadult age classes can be recognized. Subadults that are 1 year old have a downy tuft at the tip of the pointed tail feathers, whereas this downy tuft is lost by a bird's second year (Moen et al. 1991). Adult (i.e., more than 27 to 28 months old) birds have rounded tips on the tail feathers, which usually are mottled in color.

Range And Distribution

The range of a species is that general geographic area within which the species may occur. A species' distribution may be synonymous with its range or it may be specific to the habitat types in which it occurs within its range. Northern spotted owls are found from southern British Columbia, Canada, south to Marin County, California. They range eastward through this area to the edge of the Palouse prairie in Washington and the Great Basin shrub steppe in Oregon and California. Although northern spotted owls are sighted in almost all areas of their general range (e.g., urban areas, beach dunes), their breeding distribution is restricted to forest communities (see Habitat). They are found from sea level to as high as approximately 7,500 feet in the southern portion of their range and to approximately 4,000 feet in elevation in the northern part of their range. Densities of owls vary across this broad range according to habitat type, habitat quality, and habitat quantity (Thomas et al. 1990). The current distribution of known spotted owls within their historic range is in Figure 2.1.

Taxonomy And Genetic Relationships

Spotted owls are members of the largest family, Strigidae, within the order Strigiformes. Some controversy exists regarding the taxonomic and systematic relationships of birds within this order (Sibley et al. 1988, Cracraft 1981), although most of the discussion centers on higher taxonomic levels. The genus *Strix* is a widely distributed group of owls with members occurring in the Nearctic, Palearctic, Neotropical, and Indian fauna regions (Clark et al. 1978). In North America there are three species of *Strix:* the spotted owl, the barred owl (*Strix varia*), and the great gray owl (*Strix nebulosa*; Johnsgard 1988). *Strix* owls may be most closely related genetically to owls in the genus *Athene* (Randi et al. 1991).

Spotted owls were described by early naturalists as three subspecies (the northern spotted owl; the California spotted owl, *Strix occidentalis occidentalis;* and the Mexican spotted owl, *S. occidentalis lucida*). The California spotted owl was first described by Xantus (1859) from a specimen collected in the

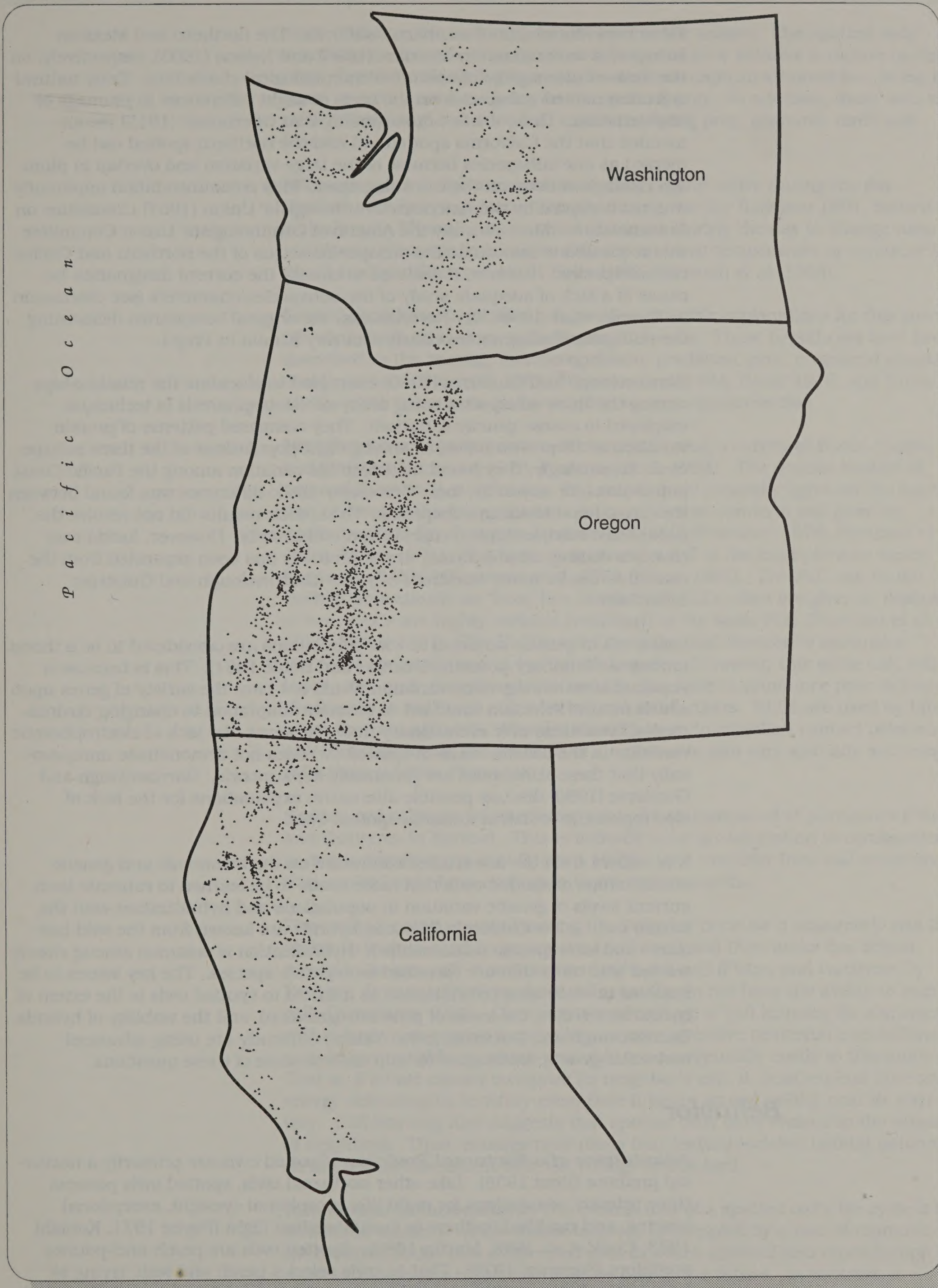


Figure 2.1 Distribution of known spotted owl pairs located in Washington, Oregon, and California between 1986 and 1990.

Tehachapi Mountains of southern California. The northern and Mexican subspecies were named by Merriam (1898) and Nelson (1903), respectively, on the basis of plumage color and other morphological characters. Early naturalists often named subspecies on the basis of slight differences in plumage or size variation. Thus, it was not surprising that Oberholser (1915) recommended that the California spotted owl and the northern spotted owl be merged as one subspecies because of the large variation and overlap in plumage characters between the two subspecies. This recommendation apparently was not accepted by the American Ornithologists' Union (1957) Committee on Nomenclature. More recently the American Ornithologists' Union Committee was requested to reevaluate the subspecific status of the northern and California subspecies. However, it declined to change the current designation because of a lack of adequate study of the subspecies characters (see discussion in Thomas et al. 1990:59). Nevertheless, the original boundaries delineating the subspecies' ranges were clearly arbitrary (Gould In Prep.).

Barrowclough and Gutiérrez (1990) attempted to elucidate the relationships among the three subspecies using allozyme electrophoresis (a technique employed to assess genetic variation). They compared patterns of protein variation at 19 presumptive loci among eight populations of the three subspecies. Surprisingly, they found no detectable variation among the Pacific Coast populations for any of the loci. One major allelic difference was found between the coastal and Mexican subspecies. Thus, their results did not resolve the subspecific relationships of *caurina* and *occidentalis*. However, *lucida* was clearly a distinguishable taxon, and it probably has been separated from the coastal forms for many hundreds of years (Barrowclough and Gutiérrez 1990:742).

Low levels of genetic variation in wild populations are considered to be a threat to their evolutionary potential (Frankel and Soulé 1981). This is because a population with low genetic variation would not have the variety of genes upon which natural selection could act to promote adaptation to changing environmental conditions over evolutionary time. However, the lack of electrophoretic variation in the coastal forms of spotted owl does not demonstrate unequivocally that these subspecies are genetically depauperate. Barrowclough and Gutiérrez (1990) discuss possible alternative explanations for the lack of electrophoretic variation found in spotted owls.

It is evident from the few studies conducted on the taxonomic and genetic relationships of spotted owls that more needs to be learned to estimate both current levels of genetic variation in populations and hybridization with the barred owl. A few California/Mexican hybrids are known from the wild (see intra- and interspecific relationships). Hybridization is common among closely related wild birds that are classified as separate species. The key issues to be resolved in evaluating hybridization as a threat to spotted owls is the extent of hybridization (i.e., the levels of gene introgression), and the viability of hybrids. Barrowclough and Gutiérrez (pers. comm.) currently are using advanced molecular genetic techniques to help answer some of these questions.

Behavior

Adaptations of a Nocturnal Predator: Spotted owls are primarily a nocturnal predator (Bent 1938). Like other nocturnal owls, spotted owls possess three primary adaptations for night life: exceptional eyesight, exceptional hearing, and modified feathers to facilitate silent flight (Payne 1971, Konishi 1973, Clark et al. 1978, Martin 1986). Spotted owls are perch-and-pounce predators (Forsman 1976). That is, owls select a perch and wait, trying to locate potential prey either by sight or sound; once prey is detected, they try to capture it with their talons. If prey is located in an inaccessible location or at

some distance, the owls may move closer to the animal. The spotted owls' silent flight allows them to fly close to potential prey without detection by the prey. Spotted owls are agile creatures and can capture arboreal (i.e., living in trees) or terrestrial (i.e., living on the ground) prey. In addition, these owls will exhibit "hawking" behavior (i.e., capturing flying prey, primarily birds and insects).

Although spotted owls are nocturnal, they can be active during the day. Spotted owls forage opportunistically during the day (Laymon 1991, Sovern et al. In Prep.). They also move short distances during the day to change roosting position in response to changes either in ambient temperature or exposure to direct sunlight (Barrows 1981, Solis 1983, Forsman et al. 1984).

Several hypotheses have been proposed as possible explanations for this species' affinity for late seral stage and old-growth forests. These hypotheses have been described as the nesting, thermoregulation, predation, prey, or general adaptation hypotheses (Barrows 1981, Forsman et al. 1984, Carey 1985, and Gutiérrez 1985). Each hypothesis is discussed in an appropriate section.

Vocalizations: Spotted owls communicate using a variety of hoots, "barks," and whistles (Forsman 1976, Forsman et al. 1984). The precise context of some of these calls is unknown, but researchers generally agree on the function of some of the more common calls. The most common call given by spotted owls is the four-note location call (FLC) (Forsman 1976, Forsman et al. 1984, Fitton 1991). The next most common call is the multiple-note series location call (SLC) (Forsman et al. 1984, Fitton 1991). The FLC can be described phonetically as "hooo hoo hoo hooo." FLCs often are given in replicates of two. SLCs are highly variable renditions of the basic FLC (Forsman et al. 1984, Fitton 1991). The FLC is used by males and females to announce territory occupancy and in territorial disputes. However, this same call, with lower pitch and intensity, also is used by the male to announce prey delivery to the female as well as in other behavioral interactions. SLCs are used by birds when they are agitated. Whistles usually serve to establish contact between a pair (Forsman et al. 1984). Calls of spotted owls also vary spatially and temporally (Ganey 1990, Fitton 1991).

Spotted owl calls are relatively low-pitched and composed of pure tones (Fitton and Gutiérrez In Review). This is believed to be an adaptation to communicate in dense (forest) vegetation (Morton 1975). One can infer from call structure that spotted owls have evolved in forest environments.

The spotted owl is unusual among the Strigidae because it apparently has the ability to learn a neighboring spotted owl's call and then make fine adjustments to its own call to imitate the neighbor's call (Fitton and Gutiérrez In Review). Primitive birds such as owls usually do not have the ability to learn calls (Kroodsma 1982). One adaptive advantage of call learning for a species with a large home range may be to prevent aggressive territorial interactions with known neighbors, which probably are energetically costly to this animal. That is, if a bird cannot recognize its neighbor's call, it must expend time and energy defending its territory every time it hears an owl calling near its territory. Call learning also suggests that spotted owls have evolved in the presence of neighbors. Thus, management plans that feature isolated habitat patches do not appear consistent with the biology of this bird.

Intersexual Relationships: The central unit of a spotted owl's life cycle is a functional territory. A functional territory is occupied by a pair of reproductively active birds. It is a defended area in which survival and reproduction are sufficient to ensure replacement of the pair in the future. In contrast, a nonfunctional territory would be a defended area in which the habitat conditions did not allow either successful reproduction or reliable survival of off-

spring. Territories probably are smaller than home ranges, but the exact relationship between the defended area and the used area is unknown. Both members of a pair vigorously defend the territory through vocalizations and visual displays. This propensity to defend a territory also is the key to successful study of the species because one can locate the birds through imitation of their calls.

Spotted owls often form long-term pair bonds (Forsman et al. 1984). Pair bonds do occasionally dissolve, but the reasons for "divorce" are unknown (Franklin and Gutiérrez unpubl. data). Nevertheless, several behaviors occur commonly among spotted owls that serve to illustrate mechanisms that probably have evolved to reinforce pair bonds. Calling serves to strengthen pair bonds when it is given in the appropriate context (e.g., nest site selection, prey delivery). Courtship feeding by the male is common during the early part of the nesting cycle (Forsman 1976) and may serve as a proximate cue to either food availability or the male's ability to hunt successfully. Finally, physical contact, as exemplified by "allopreening" (i.e., mutual preening of feathers), also serves to strengthen pair bonds (Forsman and Wight 1979). Allopreening is common in other *Strix* owls (Fitzpatrick 1975, Nero 1980), and is ingrained so strongly in these birds that captured owls may engage in allopreening with their captors (Nero 1980).

The nesting cycle begins with the return of the pair from the wintering area to the nesting area in late winter or early spring (late February to early March). The pair begins to roost together on a more frequent schedule as day length increases. The initiation of laying is contingent upon the physical condition of the female, the availability and abundance of prey, and the ability of the male to capture sufficient prey. The condition of the female probably depends on the female's hunting experience and the prey levels within the territory during the winter and the preceding fall. Once a pair is committed to nesting, the female lays her clutch of eggs and incubates and broods the young without assistance from the male. In fact, during incubation and the first half of the brooding period, the female leaves the nest only to defecate, regurgitate pellets, avoid predation, defend against conspecifics (i.e., other spotted owls), or receive prey delivered by the male. The role of the male is to provide sufficient food to the female so that the female need not forage. Once the young have hatched, the juveniles remain 3 to 5 weeks before leaving the nest. Owlets often leave the nest before they can fly, simply jumping from the nest into the surrounding tree branches or onto the ground. These young birds are fed and tended by one or both of the adults until they disperse in early fall (late September or early October, see Dispersal). Following dispersal of the young birds, adult birds begin to expand their home ranges and to roost together less frequently, signaling an end to the annual reproductive cycle.

Intra- And Interspecific Relationships

Competition: Intraspecific competition is the competition for resources among members of the same species. Territoriality is one expression of intraspecific competition. One adaptive advantage of territoriality is that it allows a territory holder to sequester resources for exclusive use. Because spotted owl prey are patchy in distribution and variable in abundance (Ward 1990), it is important, if not necessary, for spotted owls to defend territories and use large areas for foraging.

Preliminary information on habitat selection gathered by Solis and Gutiérrez (1990) and Sisco (1990) suggest that intersexual (competition between males and females of the same species) competition may have led to foraging habitat segregation between males and females. It appears that males and females select forests of different structure, and that the smaller males hunt in denser

forests. Alternatively, habitat selection by each sex may be the result of reversed sexual dimorphism, which may have evolved for other reasons besides food competition (Muller 1986).

Competition for resources can occur between different species, this is commonly called interspecific competition. The use of any finite resource in one area by more than one species can result in competition, if the depletion of the resource by one species negatively affects another species. Competition is commonly invoked as a selective mechanism for the evolution of niche partitioning (Cody 1974). For example, the relative differences in body size of members of the Pacific Northwest owl community may be an expression of past competition that led to the evolution of differences in body size and foraging strategies that minimize diet or habitat overlap. Alternatively, the owl community structure simply may be an expression of adaptive radiation (adapting to regional environmental conditions) at some time in the past (Wiens 1989). Nevertheless, competition can be a serious problem for a species when an exotic (nonnative) animal of similar body size and ecological requirements invades its habitat. The recent invasion of the barred owl into the range of the spotted owl (Taylor and Forsman 1976) is an example of potential competition between closely related species. Barred owls are larger and more aggressive than spotted owls in interspecific territorial interactions. They also feed on a broader range of prey, occupy a wider range of habitats, and have smaller annual home ranges than do spotted owls (Hamer 1988). Further, they are known to have to have displaced spotted owls from their territories (Allen pers. comm.). Thus, barred owls are a competitive threat to spotted owls.

Hybridization: At least three spotted owl/barred owl hybrids have been observed in the wild (Forsman pers. comm.). It is common in nature for closely related species to hybridize, especially where habitat disruption has occurred (Short 1965, Johnsgard 1970, Mayr and Short 1970, Short 1972). Vincent (1990) expressed concern about the recent invasion of barred owls and the potential effect of hybridization on the integrity of the spotted owl as a species. Several biological outcomes are possible given the rapid expansion of barred owls into the range of the spotted owl. First, the barred owl could, through extensive hybridization, genetically "swamp" the spotted owl. Second, a "hybrid swarm" could develop in specific areas of contact. Third, selection could act against hybrids, thus favoring development of effective isolating mechanisms. Fourth, low levels of hybridization could occur continuously without loss of the identity of either species. Fifth, hybridization could be a random event. In only the first case is the genetic integrity of the spotted owl seriously challenged. However, in declining populations any loss of spotted owl reproductive capacity to hybridization must be considered a real threat, but primarily because of its effect on the short-term demography of the species.

Predation: Another form of interspecific interaction is predation (the killing of one organism by another for food). As a medium-sized owl, the spotted owl kills and eats smaller owls. Therefore, it is not surprising that the larger great horned owl *(Bubo virginianus)* kills and eats spotted owls. This is called a food chain. Predation by great horned owls on spotted owls is a potential hypothesis to explain spotted owl use of old-growth forests, or to explain spotted owl avoidance of open habitats (Forsman et al. 1984). These two species commonly share the same habitats, but great horned owls tend to occupy sites that are more fragmented and open than those used by spotted owls (Johnson pers. comm.), perhaps because their large size makes them less maneuverable in dense forest. There is no current test of this hypothesis (i.e., relative predation rates by great horned owls on spotted owls using habitats with different structure). However, great horned owls probably prey on spotted owls opportunistically rather than seeking spotted owls as prey (Forsman pers. comm.).

Northern goshawks *(Accipiter gentilis)* also prey on adult and juvenile spotted owls (Forsman et al. 1984, Gutiérrez et al. 1985, Miller 1989, Johnson 1991 pers. comm.). Nevertheless, spotted owls will nest within a goshawk territory (Forsman et al. 1984) and will defend their young against attacks by goshawks (Gutiérrez unpub. data). Thus, goshawks probably are not serious threats to spotted owl populations.

Until recently, people rarely have encountered spotted owls and there has been no historic persecution by humans of this docile creature. The recent, conspicuous rise in spotted owl deaths at the hands of humans is a potential threat to local owl populations.

Diseases and Parasites

Disease and parasite infections represent another form of interspecific interaction because it is the relationship (in the broad biological meaning) of one organism with another. However, the topic of pathogens is treated separately here because it is treated separately in status analyses by the FWS when listing a species as threatened or endangered.

Relatively little is known about the diseases and parasites of spotted owls. Gutiérrez (1989) conducted an extensive survey of hematozoan parasites (those that live in the blood) among all three subspecies of the spotted owl. Of the six hematozoan species found, all but one species occurred in the northern spotted owl. The infection rate was 100 percent, which was one of the highest rates of infection by these parasites recorded among birds (Greiner et al. 1975). However, spotted owls must be adapted to carry these high parasite loads because their survival rates are very high where infection rates are high (e.g., northwestern California, see following text). Hoberg et al. (1989) examined 20 northern spotted owls for helminth (worm) parasites and found eight species, representing nematodes (round worms), cestodes (flat worms), and acanthocephalans (spiny-headed worms). More than 80 percent of the birds were infected with at least one species; and multiple infections were common. Young et al. (In Review) reported two hippoboscid fly (louse) species from spotted owls in northwestern California. One species of fly was recorded only once among the 382 owls examined, but approximately 17 percent of the owls they examined were infested by the other species. Fly densities on owls were higher in years of higher summer and fall temperatures and lower winter precipitation. The authors speculated that low temperatures may have depressed survival of fly pupae. Finally, Forsman (pers. comm.) observed two nests where owlets had such high infestations of hippoboscids that the flies caused severe trauma to the young birds.

Habitat

Habitat selection and its context: Perhaps the most controversial aspect of the natural history of the spotted owl concerns its habitat requirements. Thomas et al. (1990:143-144) discussed the complex habitat needs of the northern spotted owl.

Most species exhibit variation in habitat selection (i.e., most species are not strict habitat specialists). Spotted owls are known to use many habitats. Empirical observations of spotted owls in different habitats can provide understanding of the birds' habitat requirements at three different levels (Peek 1986). *Habitat use* is the simple observation of an animal in a habitat without understanding the context of the observation. *Habitat selection* is the choice of a habitat or habitats among those that are directly available to the animal. *Habitat preference* is the selection of habitat that would be made by an animal

if all habitats were available to the animal. Thus, we have many observations of spotted owl habitat use, fewer studies of habitat selection, and no studies of habitat preference as defined by Peek (1986). Early studies portray the northern spotted owl as a denizen of primal forests (Grinnell and Miller 1944) based on observations of habitat use. However, Grinnell and Miller (1944) found that geographic variation in habitat use did exist in spotted owls. Subsequent investigations (Forsman 1976, 1980, Solis 1983, Forsman et al. 1984, Gutiérrez et al. 1984, Solis and Gutiérrez 1990, Sisco 1990, Blakesley et al. In Press, Bart and Forsman 1992) reaffirmed the naturalists' notions from observations of habitat use, but more importantly, provided analyses of habitat selection. Recent surveys of managed (i.e., previously logged private lands) forests have added to the knowledge of habitat use (Diller 1989, Irwin et al. 1989a, 1989b, Kerns 1989, Pious 1989). These latter observations are important, but their ecological significance is enigmatic because, unlike studies conducted on public land, there is no supporting demographic information. It is essential that more demographic information be gathered to evaluate these populations (see section on spotted owl use of young, managed timberlands).

Variation in habitats used: Spotted owls are known to nest, roost, and feed in a wide variety of habitat types and forest stand conditions throughout their distribution (see discussion of suitable habitat elsewhere in this document). Spotted owls use western hemlock, mixed evergreen, mixed conifer, Douglas-fir, redwood, Douglas-fir/hardwood, evergreen hardwood, ponderosa pine, western red cedar, and other forest types in different parts of their range. Most observations of spotted owl habitat use have been made in areas having a component of old-growth and mature forests (Solis 1983, Forsman et al. 1984, LaHaye 1988, Sisco 1990, Ward 1990, Zabel et al. In Prep.; see additional summaries in Thomas et al. 1990). However, observations of spotted owls in managed (i.e., previously logged) stands are commonplace (Diller 1989, Kerns 1989, Pious 1989). Studies evaluating habitat selection show owl selection for mature and/or old forest stands with concomitant selection against young stands (Forsman 1980, Solis 1980, Carey et al. 1990, Blakesley et al. In Press). Selection for forest stands of intermediate age and size vary among the owls studied.

Nesting habitat: Most northern spotted owl nest sites observed on public lands have been located in old-growth or mature forests (Forsman et al. 1984, LaHaye 1988). In addition, the proportion of older seral stage forest surrounding nests has been significantly greater than it was in surrounding random sites in the same area (Meyer et al. 1990, Ripple et al. 1991). In areas of private managed forest, particularly in the California Klamath and California Coast physiographic provinces, where some uneven-aged silviculture has occurred or where fast tree growth facilitates rapid habitat development, spotted owls are known to nest in managed stands, especially if residual old-growth characteristics are present (Forsman et al. 1977, Diller 1989, Pious 1989, Thomas et al. 1990; see Appendix B).

Spotted owls do not build their own nests; they depend upon suitable naturally occurring nest sites. In older-age forests, owls tend to nest in broken-top trees and cavities; they use platforms (i.e., abandoned raptor nests, squirrel nests, mistletoe brooms, debris accumulations) less frequently (Forsman et al. 1984, LaHaye 1988). In younger forests (i.e., forests less than 150 years old), nests more frequently are found on platforms (LaHaye 1988, Irwin et al. 1989a, Buchanan 1991). In one California study (LaHaye 1988), the proportion of platform nests used by spotted owls increased north to south, but the trend probably is related to the distribution of stand ages in that study rather than latitude.

The presence of suitable nest sites has been hypothesized as one possible basis for the use of old-growth by spotted owls (Forsman et al. 1984). However, owls

also use a variety of nest sites in younger-aged stands. But one critical piece of information should be assessed before this hypothesis can be tested. That is, the relative nesting success of birds using cavities and broken-top sites should be compared to that of birds using the presumably structurally less stable debris platforms. In any event, artificial nest sites probably could be provided for these birds (Madison and Woodbridge pers. comm.). European owls in the genus *Strix* readily use nest boxes (Southern 1970, Saurola 1989). If spotted owls behave in a similar fashion to other *Strix* owls, the availability of nest sites probably is not a critical management problem. However, a critical study of nest-box acceptance by spotted owls has not been conducted.

Several studies have been conducted on the structure of spotted owl nesting habitat (LaHaye 1988, Buchanan 1991, Self and Nelson 1991 pers. comm.). In the two studies that compared nest sites with available habitat, one in unmanaged forest and the other in managed forest (LaHaye 1988 and Buchanan 1991, respectively), owls nested in forests that differed from what was available to them, suggesting selection by the owls. In general, owls preferentially used forests with greater complexity and structure. Nesting habitat structure reported by Self and Nelson in managed forests (1991 pers. comm.) was strikingly similar to the habitat structure used by foraging spotted owls in unmanaged stands within the same province (Solis 1983).

Roosting habitat: Northern spotted owl roosting habitat has been described by Forsman (1976), Barrows and Barrows (1978), Forsman (1980), Solis (1983), Forsman et al. (1984), Chavez-Léon (1989), Sisco (1990), and Blakesley et al. (In Press). Roost sites are typically areas of relatively dense vegetation (high canopy closure dominated by large-diameter trees). During the summer these sites are usually cool, shady spots near streams or are on the lower third of slopes (possibly a simple correlation with stream position; Forsman 1976, Solis 1983, Blakesley et al. In Press). Spotted owls respond to variation in temperature and exposure by moving within the canopy to find favorable microclimate conditions (Forsman 1976, Barrows and Barrows 1978, Forsman 1980, Barrows 1981, Solis 1983, Forsman et al. 1984). The multistoried stand structure of roost sites facilitates this movement. Because of this observed behavioral response to variation in temperature, it has been hypothesized that old-growth forests are necessary to spotted owls for them to avoid heat stress (Barrows and Barrows 1978). However, Gutiérrez (1985) pointed out that there are other plausible hypotheses to explain the associated owls with old-growth.

Foraging habitat: Of the major spotted owl habitat categories, feeding habitat appears to be the most variable (summarized in Thomas et al. 1990). This is predictable given the highly variable distribution and abundance patterns of the owl's primary prey (Ward 1990). Within a given geographic province, foraging habitat may be more variable than either nesting or roosting habitat. Nevertheless, spotted owl foraging habitat is characterized by high canopy closure and complex structure. Comparisons of habitat among unmanaged stands used by foraging owls and managed stands occupied by nesting owls shows a surprising concordance of structural habitat features in California (Appendix B).

Solis and Gutiérrez (1990) presented evidence that male and female spotted owls may segregate their foraging habitat. The smaller males appeared to be using stands that had higher tree density than were the larger females, which foraged in less dense habitats. Earhart and Johnson (1970) suggested that differential habitat use by male and female owls may occur because the high wing loading of the females would make them less maneuverable than males. However, this probably would be a consequence rather than a cause of re-versed sexual dimorphism (Muller 1986, Solis and Gutiérrez 1990).

Spotted owl use of young, managed timberlands: The significance of the owl's relationship to old-growth forests (*sensu* Old-growth Definition Task Group 1986) is obvious: old-growth forests are declining rapidly throughout the owl's range as a result of logging (Thomas et al. 1990, USDI 1990). If northern spotted owls are ecologically dependent (Ruggiero et al. 1988) on old-growth or mature forests, then continued logging of their habitat will lead to the probable extinction of the population (Thomas et al. 1990, USDI 1990). However, Forsman et al. (1977), Forsman (1988b), and Hays et al. (1989) reported spotted owls occupying young, managed stands at lower densities than in old-growth stands. A managed stand is defined in a broad context, that is, managed stands in which cutting of trees has occurred. This clarification is necessary because there are no examples of forests in which logging or silviculture has occurred where the response of owls is documented experimentally. Further, Forsman (1980), Solis (1983), Forsman et al. (1984), LaHaye (1988), Chavez-Leon (1989), Solis and Gutiérrez (1990), and Sisco (1990) describe habitat used by northern spotted owls in both old-growth and mature stands. Their descriptions of mature forest structure used by spotted owls is similar to the structure of uneven-aged managed forests in northwestern California (Appendix B). Thus, it is not surprising that spotted owls are being observed in younger managed timberlands throughout the distribution of the subspecies (Diller 1989, Irwin et al. 1989b, 1989c, Kerns 1989, Pious 1989). There is hierarchy of information needed to assess and understand these observations of owls in managed forests. In order of increasing importance, these classes of information are 1) presence of individuals, 2) presence of pairs, 3) density, 4) variation in reproduction, 5) survival schedules, 6) dispersal patterns, 6) ratio of internal to external recruitment, and 7) population stability. The structure and proportions of habitats used by owls relative to available habitats are also necessary to evaluate the observations. Finally, future harvest patterns must be known and must accommodate owl needs in order to predict the effects of the logging activities on the birds inhabiting these managed timberlands.

On one side, this habitat variation argues that spotted owls are not habitat specialists. On the other side, it suggests that spotted owls show adaptive responses to regional variation in environmental conditions. Regional variation in habitat selection by owls does not indicate that they will respond positively to any human-induced habitat changes in one part of their range that lead to habitat conditions similar to those used by owls in other parts of their range. An additional problem in assessing variation in habitat use is the lack of a consistent definition of vegetation seral stage classification (see Table F1 in Thomas et al. 1990). Terms such as "old-growth, mature, young age, unmanaged, managed, second-growth" are defined in the literature using different parameters and criteria. This impedes rather than facilitates communication among interested persons.

Owls in managed forests within the California Klamath and California Coast provinces usually occupy stands with high structural diversity, high canopy closure, and either large-diameter trees or residual old trees (Appendix B). These stands are usually more than 60 years old after partial logging events of the past (Thomas et al. 1990). For example, stands in the redwood region of the California Coast province described by Kerns (1989) have a structure similar to unmanaged (i.e., not previously logged) mature stands occupied by owls in a nearby national forest (Solis and Gutiérrez 1990). Apparently, the fast growth of redwood trees, presence of understory hardwood trees, and the remnant old trees within the stands facilitate rapid structural development of these coastal forests. Critical aspects yet to be estimated in previously harvested forests are the survival, recruitment, dispersal, and reproductive patterns of these birds relative to conspecific populations in unlogged forests.

Home Range Size

Home range is defined generally as the area used by an animal and to which the animal exhibits fidelity. The size of home ranges of spotted owls is a focal point of controversy because of their large size (Table 2.1; Thomas et al. 1990).

Forsman (1980) was the first to critically estimate spotted owl home range size by using radio telemetry, although Marshall (1957) guessed at the nightly ranges of Mexican spotted owls in Arizona and Mexico. Radio telemetry is the only method through which scientists reasonably can estimate the size of spotted owl home ranges. There has been some concern expressed about the effect of radio transmitters on survival and reproduction (Paton et al. 1991). Foster et al. (1992) found no significant differences in survival or body mass between radio-marked and unmarked spotted owls, although some owls did die as a result of improper transmitter attachment. But they did record a significant negative effect on reproductive output of radio-marked owls.

Because of Forsman's (1980) initial observations that spotted owl home ranges were very large (more than 2,000 acres on the average) a great deal of scientific effort has been devoted to verifying his original observations as well as estimating the geographic and inherent variation in spotted owl home ranges (Forsman 1981, Solis 1983, Forsman et al. 1984, Gutiérrez et al. 1984, Sisco and Gutiérrez 1984, Forsman and Meslow 1985, Allen et al. 1989, Hamer et al. 1989, Hays et al. 1989, Carey et al. 1990, Paton et al. 1990, Sisco 1990, Thrailkill and Meslow 1990). In addition, Thomas et al. (1990) summarized this information as well as other unpublished estimates of home range size (see Table 2.1).

Interpreting the variation in home range size and habitat use has been a significant challenge to spotted owl ecologists. Variation (i.e., the distribution of observations of a trait) in observed home range size has formed the basis upon which scientific inference and generalization were based about spotted owl home range requirements. From the studies cited earlier, some generalizations can be made about home range characteristics. First, all studies of home range size are consistent with Forsman's (1980) original observations of large spotted owl home ranges (see Table 2.1). Second, there is a large degree of overlap in home range areas between members of the same pair (Forsman et al. 1984, Solis and Gutiérrez 1990) and lesser overlap among adjacent pairs (Forsman et al. 1984). Third, there is considerable geographic variation in home range size, with owls occupying Washington's Olympic Peninsula having the largest home ranges (Thomas et al. 1990). Fourth, home range size increases as the amount of old forest within the home range decreases (i.e., loss of habitat from logging; Carey 1985, Forsman et al. 1984, Thrailkill and Meslow 1990). It is unknown if this geographic variation is related to latitude, habitat, individual, temporal, or prey-base variation.

The size of an owl's home range probably is dependent on many factors (e.g., food availability, interspecific competition, amount and arrangement of suitable habitat). For example, spotted owl home range size may be a reflection of an adaptive response to low prey abundance and variation in abundance and distribution of prey (Ward 1990). Further, estimates of owl home range size can be influenced by the sampling design of the home range study and the home range estimator used in the analyses (Carey et al. 1989, Call 1989). Although these factors may influence the estimation of owl home range size, predictions of home range sizes of birds of the size and trophic level of spotted owls based on allometric equations are similar to empirical estimates of spotted owl home ranges (Schoener 1969). Predictions of spotted owl home range size, based on allometric analysis of mammals, underestimate direct observations of

Table 2.1. Median annual home range areas (in acres) of spotted owl pairs in different study areas and physiographic provinces.[a]

State / Location / Site	No. of Pairs	Forest Type[b]	Range: Median	Range: Min	Range: Max	Sources[c]
California						
Klamath Mountains						
Ukonom	9	MC	3,314	2,056	7,823	1
Mad River	12	MC	2,975	1,803	4,685	1
Willow Creek	2	MC	1,692	1,258	2,126	2
Oregon						
South Coast						
Chetco	4	MH	5,614	5,327	6,197	1
Klamath Mountains						
South Umpqua	3	MC	1,411	1,035	1,504	3
Cow Creek	6	MC	4,106	2,499	7,494	3
Coast Ranges						
Tyee	5	DF/HEM	3,387	1,880	8,272	3
Peterson	4	DF/HEM	6,318	3,483	10,189	3
Eugene BLM	4	DF/HEM	6,390	3,715	8,180	4
Other[d]	4	DF/HEM	4,183	2,849	9,748	5
Kellogg[e]	5	MC	4,072	1,618	6,281	3
Western Cascades	11	DF/HEM	2,955	1,443	9,758	6,7
Washington						
Western Cascades	11	DF/HEM	6,657	2,969	17,942	8,9,10
Olympic Peninsula	10	HEM/DF	14,271	4,497	27,309	9,11

(Note -Table follows Thomas et al. (1990) with changes based on Forsman and Hays (pers. comm.))

[a]Pair ranges were calculated by delineating 100 percent MCPs (minimum convex polygons): total = exclusive area of male + exclusive area of female + the area of overlap shared by the two sexes.

[b]MC = mixed conifer, MH = mixed conifer/evergreen, DF/HEM = Douglas-fir, western hemlock, HEM/DF = mostly western hemlock with Douglas-fir intermixed.

[c]1 = Paton et al. (1990), 2 = Solis (1983), 3 = Carey (pers. comm.), 4 = Thrailkill and Meslow (pers. comm.), 5 = Carey et al. (1989), 6 = Forsman and Meslow (1985), 7 = Miller (pers. comm.), 8 = Allen et al. (1989), 9 = Hays et al. (1989), 10 = Hamer (pers. comm.), 11 = Forsman (pers. comm.).

[d]Includes four sites in the southern Coast Ranges near Roseburg.

[e]This was a relatively dry area bordering the Umpqua River Valley, characterized by mixed conifer forest more typical of the Oregon Klamath province than the Coast Ranges.

owl home ranges (Harestad and Bunnell 1979, Lindstedt et al. 1986). Thus, because spotted owls do not fit theoretical predictions of their home range size based on mammalian allometric analysis, it should not be expected that they can survive and reproduce in a much restricted home range based on extrapolation from studies of mammals (SOW 1991).

One important feature of an owl's home range is the amount of suitable habitat within the boundaries of the home range. Thomas et al. (1990) summarized the amounts of old-growth and mature forest within spotted owl pair home ranges (see Table 2.2). The median amount of these late seral stage forests for a number of studies within the northern spotted owl's range was 615 to 4,579 acres. In only three studies were median amounts of these forest less than 1,000 acres. In one of these studies (Solis 1983), the sample was small (two

Table 2.2. Median amounts of old-growth and mature forest (in acres) in annual pair home ranges of spotted owls, by state and physiographic province.

State / Location / Site	Number of Pairs	Forest Type[b]	Median	Min	Max	Sources[c]
California						
Klamath Mountains						
Ukonom	9	MC	2,484	1,030	5,654	1,2
Mad River	12	MC	1,365	835	1,953	1,2
Six Rivers National Forest	2	MC	800	367	1,233	3
Oregon						
Klamath Mountains						
South Umpqua	3	MC	615	563	768	4
Cow Creek	6	MC	1,549	1,450	1,983	4
Coast Ranges						
Tyee	5	DF/HEM	2,031	1,645	3,984	4
Peterson	4	DF/HEM	2,609	1,284	3,196	4
Eugene BLM	4	DF/HEM	1,783	799	3,580	5
Other[c]	4	DF/HEM	2,375	1,795	2,625	6
Kellogg[d]	5	MC	1,018	697	1,983	4
West Slope Cascades	9	DF/HEM	1,796	1,050	3,786	7,8
Washington						
West Slope Cascades	11	DF/HEM	3,281	1,715	8,998	9,10,11
Olympic Peninsula	7	HEM/DF	4,579	2,787	8,448	12

(Note: -Table follows Thomas et. al. (1990) with changes based on Forsman and Hays (pers. comm.))
[a]MC = mixed conifer, DF/HEM = Douglas-fir, western hemlock, HEM/DF = mostly western hemlock with Douglas-fir intermixed.
[b]1 = Paton et al. (1990), 2 = Paton (pers. comm.), 3 = Solis (1983), 4 = Carey (pers. comm.), 5 = Thraikill and Meslow (pers. comm.), 6 = Carey et al. (1990), 7 = Forsman and Meslow (1985), 8 = Miller (pers. comm.), 9 = Allen et al. (1990), 10 = Hays et al. (1989), 11 = Hamer (pers. comm.), 12 = Forsman (pers. comm.).
[c]Includes four sites in the southern Coast Range near Roseburg.
[d]This was a relatively dry area bordering the Umpqua River valley, characterized by mixed conifer forest more typical of the Oregon Klamath province than the Coast Ranges.

pairs) and the pairs were sampled only for a short time. Thus, both the home ranges and the amount of late seral stage habitat of the study birds were likely to have been underestimated. In any event, the object of Solis' (1983) study was to quantify owl habitat structure and not to provide an accurate estimate of home range size. In the second study (Carey in Thomas et al. 1990:197), the sample of pairs was small and the study was located in an area of clumped habitat distribution. In a third study, Kerns (1989) reported on the habitat use of eight spotted owls occupying "managed" redwood forest with less than 1 percent old-growth, although he did not estimate home range sizes of his marked owls. However, stands used by owls in Kern's (1989) study often contained residual old-growth trees and also had a structure similar to mature forests.

Some animals do not exhibit fidelity to an area, and are considered to be nomadic. Juvenile animals often wander widely in search of a secure home range. Such wandering animals are engaging in dispersal. Some birds may move within or among the territories of other birds, without exhibiting fidelity

to any particular area. These birds often are referred to as "floaters." The ecology of floaters is critical to understanding the dynamics of spotted owl populations, but we know the least about them (Franklin In Press).

Food Habits

Diet: Although spotted owls take prey from a broad array of taxa (e.g., mammals, birds, insects), they primarily eat small mammals (Marshall 1942, Barrows 1980, 1985, 1987, Solis 1983, Forsman et al. 1984, Laymon 1988, Richards 1989, Thraillkill and Bias 1989, Ward 1990). Three mammal species, woodrats (*Neotoma fuscipes and N. cinerea*) and flying squirrels (*Glaucomys sabrinus*), compose the majority of the prey biomass eaten by these owls (Solis 1983, Forsman et al. 1984). One of these species usually dominates the diet in an area, and this regional variation in diet is related to habitat and the distributional limits of the prey species (Forsman et al. 1984, Thomas et al. 1990).

Barrows (1985, 1987), Laymon (1988), and Thraillkill and Bias (1989) reported that the diet of breeding owls was dominated by larger prey (i.e., woodrats) whereas nonbreeding owl diets were characterized by smaller prey species. This suggested a strong ecological or evolutionary relationship between spotted owls and these larger small mammal species. Unfortunately, the small sample of owls among these studies precludes strong inference about these relationships. Thomas et al. (1990) also pointed out that large prey may be transported at a higher rate to nest sites than smaller prey. In addition, Ward (1990) and Forsman et al. (pers. comm.) were unable to document this relationship.

Spotted owl prey: Strong functional responses between prey and a variety of owl species have been demonstrated in both North America and Europe (Southern 1970, Rusch et al. 1972, Adamcik and Keith 1978, Sonerud et al. 1988, Saurola 1989). It is surprising, therefore, that until recently, little research effort has been devoted to understanding spotted owl prey and ecological responses of spotted owls to their prey. Most prey studies have been concerned with patterns of abundance and distribution of small mammals within the range of the owl (summarized by Thomas et al. 1990). One study, (Ward 1990), has related variation in prey abundance and distribution to owl reproductive success and hunting behavior, although several studies linking prey and spotted owls have been undertaken (Thomas et al. 1990). In Ward's (1990) study, woodrats were the primary prey. Spotted owls foraged in areas where the abundance of woodrats was less variable. This suggests that the owls may have been optimizing their search effort. That is, they were foraging in stands that did not necessarily contain the most abundant woodrats, but they hunted in areas where the occurrence of the animals was more predictable. Ward (1990) also showed that not only was prey abundance low but also that prey populations were variable across the landscape. These limited observations help explain the large home range sizes observed among spotted owls.

Availability of spotted owl prey has been advanced as an explanation for the occurrence of spotted owls in old-growth/mature forests (Forsman 1980, Forsman et al. 1984; also see Carey 1985, Gutiérrez 1985). Northern flying squirrels clearly depend on forest communities, but woodrats do not. Woodrats are more abundant in early seral stage vegetation (e.g., brushy areas) than they are in old-growth forests (Thomas et al. 1990). Yet spotted owls spend little time hunting in clear-cuts (Forsman et al. 1984, Solis 1983). This unpredicted foraging behavior may be related to the relative availability of woodrats to predation in the two habitats. That is, in the dense vegetation of early shrub dominated seral stages, spotted owls may not be able to capture woodrats effectively. In the more open older forests, spotted owls may be more effective predators even though the woodrats are less abundant. Thus, we

cannot reject the hypothesis that prey availability explains spotted owl selection for older age forests. In addition, if they feed in open areas, spotted owls may be killed by great horned owls (Forsman et al. 1984).

3. Life History

Reproductive Biology

Nesting phenology: Spotted owls begin their annual breeding cycle in late winter (February or March) when the pair begins to roost together. Copulation occurs during this nuptial phase (Forsman et al. 1984). Some owl pairs use the same nest site repeatedly, some use new ones each year, and others alternate nest sites from year to year. Once a clutch of eggs is laid, the female incubates the eggs for approximately 30 days (Forsman et al. 1984). After the eggs hatch, the owlets remain in the nest and usually are fed by the pair until they leave the nest. Juvenile owls leave the nest 3 to 5 weeks after hatching. Many abandon the nest site well before they are able to fly. They jump into the branches of surrounding trees or fall to the ground only to clamber up a leaning tree to a safe perch. The adaptive significance of this behavior is unknown, but Forsman et al. (1984) suggest that it serves to avoid increasing parasite loads in the nest as the season progresses. Once out of the nest the young owls are fed by the male and the female. They grow rapidly under good food conditions, reaching their parents' body mass prior to dispersal (Gutiérrez et al. pers. obser.). Although juvenile owls are dependent on their parents, they begin to hunt by late summer. Dispersal begins in the early fall, signalling the end of the annual reproductive cycle (Gutiérrez et al. 1985, Miller and Meslow 1985, Miller 1989). Therefore, spotted owls are considered to be "birth pulse" breeders (i.e., they have distinct annual breeding periods)(Caughley 1977). This knowledge is important when choosing an appropriate model with which to derive population projections.

Variation in clutch size and nesting success: Spotted owls have one of the lowest clutch sizes among North American owls (Johnsgard 1988). Normally, spotted owls lay one or two eggs (Forsman et al. 1984). A small proportion of the population will lay three-egg clutches. Records of four-egg clutches are rare (Bendire 1892, Dunn 1901). Because clutch size is small there is relatively little variation in the number of eggs laid by a female. However, there is large variation in nesting success and in the proportion of the population that breeds over time and among regions (Forsman et al. 1984, Gutiérrez et al. 1984, Thomas et al. 1990, Lutz 1992, LaHaye et al. In Press). Nesting success within a population can range from 0 to 100 percent (Forsman pers. comm., Gutiérrez et al. 1984, Gutiérrez 1991 pers. comm.). Interestingly, Franklin et al. (1990a) reported little variation in nesting during a 6-year study in northwestern California.

Fecundity: Technically speaking, fecundity is the number of female young produced per female (Caughley 1977). However, the term has been used in a variety of ways in wildlife literature. Fecundity usually is defined relative to females because it is the female segment of the population that is mathematically modeled to project population trends. Because reproductive activity varies greatly, fecundity also varies. Since biologists assume there is a 50:50 sex ratio (Noon and Biles 1990, Thomas et al. 1990, USDI 1990) in a spotted owl population, fecundity in owl populations is almost always between 0.1 and 1.5 (Thomas et al. 1990, Forsman 1988a, Franklin et al. 1990a, Lutz 1992, LaHaye et al. In Press).

Age at first reproduction: Spotted owls can breed as early as 1 year old (Barrows 1985, Miller et al. 1985). Yet most birds probably do not breed before

they are 3 years old (Franklin et al. 1990a, Thomas et al. 1990). In addition, subadult owls have lower fecundity than do adults (Franklin et al. 1990a). Age-specific fecundity also is an important demographic parameter, but there are no age-specific estimates of fecundity for the adult age classes. Therefore, for purposes of demographic modeling, adult fecundity is assumed to be equal across age classes.

Survivorship

Adult rates: Adult northern spotted owls' annual survival rates are very high. Thus, they must be long-lived birds. Based on banding and radio telemetry, the chance of an owl living from one year to the next is 81 to 96 percent (Barrowclough and Coats 1985, Lande 1985, Franklin et al. 1990a, Thomas et al. 1990). In short-term studies, survival rates may vary as a response by birds to varying environmental conditions (Gutiérrez and Pritchard 1990, LaHaye et al. In Press). Thus, in long-lived species, studies must be of long duration to achieve reliable estimates of age-specific survival rates. The most recent estimates of survival are in Appendix C.

Subadult survival: Subadult owls have a lower survival rate than adult owls (Franklin et al. 1990a, Thomas et al. 1990)(Appendix C). Since subadults also have lower reproductive rates and fecundity, it may be possible that the same environmental or behavioral factors influence all aspects of the demography of the subadults in the same way. Nevertheless, the subadult segment of the population is relatively small and makes only a modest contribution to the dynamics of the population (Noon and Biles 1990, Thomas et al. 1990).

Juvenile survival: Juvenile survival rates have been measured from banded birds and radio-marked birds (Barrowclough and Coats 1985, Gutiérrez et al. In Prep.). Survival rates for this age class are low (the chance of a juvenile living from one year to the next is 15 to 29 percent) relative to adult survival rates (Thomas et al. 1990). It is well known that first-year birds, in general, have low survival. The rigors of dispersal and the consequences of inexperience (e.g., poor hunting skills, lack of familiarity with a territory) lead to higher mortality rates.

Mortality: Spotted owls die from a variety of causes. The most frequent cause of mortality recorded among radio-marked birds is predation by other animals (Johnson pers. comm.). They also die from accidents (e.g., flying into objects, automobiles, and drowning) (Gutiérrez et al. 1985, Franklin, LaHaye, Gutiérrez pers. comm., Johnson pers. comm.). Accidents are considered to be density-independent, whereas predation usually is density-dependent in most prey, although predation may be density-independent in spotted owls. Another source of mortality is starvation. Starvation is common among spotted owls (Gutiérrez et al. 1985, Miller 1989, Johnson pers. comm.), but occurs less frequently among adult spotted owls (Sisco 1990). Starvation could be a consequence of low prey abundance, low prey availability (i.e., poor hunting habitat), or inexperience (inability to hunt successfully).

Density

The number of northern spotted owls is a topic of much debate (Thomas et al. 1990). With increasing survey and monitoring of populations, the number of known owls has increased greatly since the first estimates of total abundance were made. These observations of higher owl abundance reflect greater knowledge and effort expended by biologists to count owls; these observations should not be interpreted as evidence that the owl population is increasing. The total abundance of owls appears to be declining gradually over time (Forsman et al.

1984, Thomas et al. 1990, USDI 1990). One important step toward estimating the number of owls is to estimate their density. The density of an animal population is the number of individuals per unit area. Once an estimate of density is derived, the estimate can be used to compute an estimate of abundance for all of the area containing similar habitats or environmental conditions.

Census and monitoring of northern spotted owls have been a high priority with land management agencies and research scientists (O'Halloran 1989, Simon-Jackson 1989, Azuma et al. 1990, Max et al. 1990, Franklin et al. 1990b, Thomas et al. 1990, Ward et al. 1991). Franklin et al. (1990b) estimated the density of spotted owls in northwestern California to be 0.65 owls per square mile. They also estimated the density of owls within suitable habitat; this value was 1.51 to 1.83 owls per square mile, depending on the method used to estimate the density. Using their estimates of density, they projected declines in spotted owl populations between 60.0 percent and 82.5 percent in their area if proposed management scenarios (USDA 1988) were implemented.

Densities of spotted owls vary across their range as a function of habitat quality, geographic province, and current environmental conditions (Forsman et al. 1977, Franklin et al. 1990b, Gutiérrez and Pritchard 1990, Lutz 1992, Ward et al. 1991, LaHaye et al. In Press). Although much emphasis is placed on density, high densities can be mistaken as evidence of high quality habitat (Van Horne 1983). Density estimates are useful for relative comparisons and for evaluating management objectives, but they must be used in conjunction with knowledge of corresponding survival and fecundity values for the populations (see Habitat about spotted owl use of young, managed timberlands).

Dispersal

Dispersal among vertebrates is the process of an animal leaving one area to establish a new home range in another area. Dispersal can be undertaken by juvenile or adult spotted owls. Further, dispersal is often characterized as effective (i.e., successful breeding occurs at the end of the dispersal event) or gross (i.e., breeding may or may not be successful following dispersal) (Greenwood 1980). Scientists know a great deal more about the process and pattern of juvenile spotted owl dispersal than of adult dispersal, despite the difficulty of closely following large numbers of dispersing juvenile owls (Gutiérrez et al. 1985, Miller and Meslow 1985, Miller 1989, Gutiérrez et al. In Prep.).

Gutiérrez et al. (1985), Miller (1989), and Gutiérrez et al. (In Prep.) used radio telemetry to estimate patterns of gross juvenile dispersal. Juvenile spotted owls dispersed from their natal areas in September and October after they had reached adult body mass (Gutiérrez et al. 1985, Miller 1989). They apparently left their natal areas in random directions (Gutiérrez et al. 1985, Gutiérrez et al. In Prep.), and traveled moderate distances (approximately 9 to 30 miles on average) during their first autumn (Gutiérrez et al. 1985, Miller 1989, Gutiérrez et al. In Prep.). The pattern of dispersal varied among cohorts in a variety of ways including differences in direction, distance, and survival (Gutiérrez et al. In Prep.). Effective dispersal distance, estimated from returning banded birds averaged about 4 miles for juvenile male spotted owls and about 12 miles for female juveniles (Gutiérrez et al. In Prep.). Dispersal distances from banded birds were slightly higher for Oregon owls (Johnson pers. comm.). Estimates of dispersal distance based on studies with finite area size have been shown to be underestimates of true dispersal distance (Barrowclough 1980).

Adult spotted owls will leave mates or move from territories, but the causes of these adult dispersal events are unknown. Spotted owls normally form long,

stable pair bonds because the number of recorded adult dispersals is low. Also, the conditions surrounding these observations of adult dispersal events have not been summarized.

Demographic Projections

Because spotted owls are long-lived animals, the status of their populations is difficult to estimate. Thus, mathematical models are used to project population trends using estimates of the vital rates described earlier. Models can be deterministic (linear projections based on the estimates of the vital rates) or stochastic (projections based on random variation of specific rates or conditions). Stochastic models generally are considered to be more sophisticated because they are more complex, and they simulate variation that would be expected in natural environments. Models of both kinds have been used to evaluate spotted owl population dynamics and dispersal (Boyce 1987, Marcot and Holthausen 1987, USDA 1988, Doak 1989, Lande 1988, Noon and Biles 1990, Thomas et al. 1990, USDI 1990, Lutz 1992, Franklin In Press, Lamberson et al. In Press, LaHaye et al. In Press). In addition, Shaffer (1985) suggested that metapopulation models, in which species have populations discontinuous in time and/or space, be used to evaluate spotted owl population dynamics. Almost all modeling projections indicate that spotted owl populations are declining. However, Boyce (1987) criticized the first attempt to use a stochastic model for projecting population trends (USDA 1988) because the model did not incorporate density dependence. Density dependence is the functional response in survival probability and/or fecundity of a population to variation in density. That is, as a population declines, the density declines. Presumably, the remaining individuals in the population have more resources available to them per capita (i.e., there is less competition) and these resources then can be used by the survivors for reproduction and other life functions. Boyce (1987) argued that if a population declines numerically there should be a density-dependent response in the owl population, which would mitigate the lower density and serve to stabilize the population. In the case of the spotted owl, density has not been declining, only the abundance of owls, because habitat loss is the causative mechanism for the decline. Thus, when Thomas et al. (1990) incorporated density dependence into their metapopulation model, the projected population decline was more rapid. Most estimates of changes in northern spotted owl populations indicate that populations are declining throughout their range (Appendix C).

Models also can be spatially explicit. They can incorporate the influence of landscape character on the underlying population dynamics (Lamberson et al. In Press, Lamberson and Brooks 1991). These models are useful for developing a more complete range of alternative hypotheses to account for observed phenomena. For example, the recent observations of abundant owls in the California Coast province could be a reflection of good habitat for owls, which results in high productivity and high survival among the owls. Or alternatively, the dynamics of these redwood zone, coastal owl populations could be the result of immigration of owls from adjacent old-growth/mature forests in national forests in the Klamath province (Lamberson and Brooks 1991). The model illustrates the importance for recovery of the spotted owl throughout all of the provinces within its range (i.e., recovery of the owl in the California Klamath province probably could not be achieved if there were not a concomitant recovery in the California Coast province).

4. Conclusion

Our knowledge of the natural and life history of the northern spotted owl has grown tremendously in the past 10 years. Unlike data available on many threatened and endangered species, we have preliminary information on the demography of the owls so that initial projections of populations can be made. However, because the bird is long-lived, estimates of vital rates and, therefore, estimates of lambda (a population's finite rate of growth) may change as the populations are followed through time. These changes will occur because of normal population responses to good and poor environmental conditions as well as to habitat changes. It is evident that much more needs to be learned about the species (and other late seral stage species) to allow us to refine management plans compatible with the ecology of the species. Nevertheless, more is known about this species than about most endangered or threatened species.

II.

B. Status and Threats

The present range of the northern spotted owl approximates the limits of its historic range. The range extends from southwestern British Columbia south through the coastal mountains and the Cascade Range of Washington and Oregon, and into northwestern California as far south as San Francisco. Although the total area of the subspecies' range has not decreased, its distribution has changed greatly. The Puget Trough in Washington and lands adjacent to the Willamette Valley in Oregon no longer support populations of owls because of loss of habitat to urban, rural residential, and agricultural development. In southwestern Washington and northwestern Oregon, timber cutting and wildfires have greatly reduced habitat, and spotted owl populations are very low at present. In British Columbia, only some 20 pairs are known to exist; much of the owl's range in Canada has been logged, and little mature and old-growth forest remains.

Abundance, distribution, and habitat use of the spotted owl vary across the forest zones that occur within its range. Physiographic provinces as described by Franklin and Dyrness (1973) incorporate the physical and environmental factors that shape the landscape of the Pacific Northwest. These physiographic provinces were modified by Thomas et al. (1990) and, with slight further modification, were adopted by the Recovery Team to describe the range of the spotted owl (Figure 2.2).

1. Habitat Status

The extent of owl habitat that existed prior to logging is unknown, but by the early 1980s more than 80 percent of prelogging old-growth had been removed (Booth 1991). Although not all old-growth forests are suitable spotted owl habitat (e.g. high elevation forests), this great decrease suggests that the 7.6 million acres of habitat that remain today represent only a small portion of the area formerly occupied by spotted owl habitat (USDA 1991). Suitable habitat on national forests currently is declining about 1 to 2 percent annually. Mulder et al. (1989) projected that almost all suitable spotted owl habitat on lands suited for timber production would be gone in about 60 years on national forests and in about 30 years on BLM lands.

Remaining suitable owl habitat is not distributed evenly over the range of the species. Habitat reduction has been greatest at low elevations and in the Coast Ranges of Oregon and Washington, and this reduction is reflected in low populations of spotted owls in those areas. Remaining habitat at higher elevations may be of lower quality than that which historically was present on low-elevation lands (Thomas et al. 1990). Thus, the approximately 50 percent of remaining spotted owl habitat currently in reserved areas or in areas unsuited for timber production (Table 2.3) may not contribute proportionally to productivity, because these lands are commonly at higher elevations.

Most remaining suitable habitat is found on federal lands. The Forest Service manages about 74 percent of this habitat, the BLM about 12 percent, and the National Park Service about 7 percent. In northern California, as much as 40 percent of spotted owl habitat may be on private lands, especially along the Coast Range (Gould pers. comm.). In Oregon and Washington, however, more than 95 percent of the estimated acreage of remaining owl habitat is found on federally managed lands.

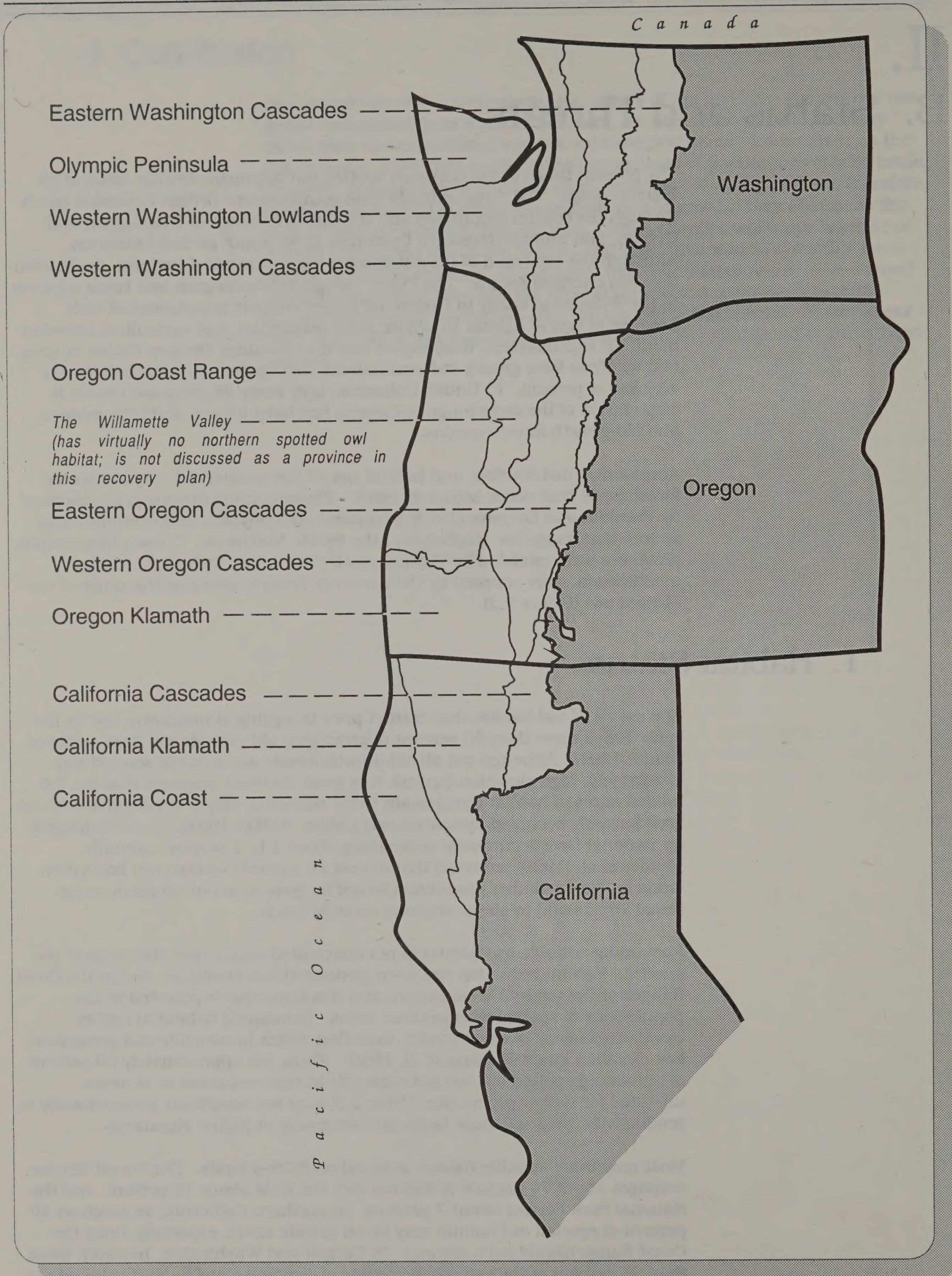


***Figure 2.2.** Provinces within the range of the northern spotted owl in the United States.*

2. Population Status

There are no estimates of the historical population size of the northern spotted owl, but owls are believed to have inhabited most old-growth forests throughout the Pacific Northwest and northwestern California, and they still are found within their historical range in most areas where suitable habitat remains (Thomas et al. 1990).

Northern Washington and southern British Columbia represent the northern extent of the range of the owl. Population densities and numbers are lowest in these areas, with fewer than 20 pairs located in extensive surveys along the U.S. border with British Columbia (Dunbar 1990). A small, potentially isolated population of about 125 known pairs of spotted owls is located on the Olympic Peninsula in and around Olympic National Park (Fredrickson et al. 1989, Washington Department of Wildlife (WDW) 1991). Fewer than 50 owls have been located in recent extensive surveys in the Coast Ranges of southwestern Washington and northwestern Oregon north of Corvallis (Forsman 1986, Forsman et al. 1987, Irwin et al. 1989b, Oregon Department of Fish and Wildlife (ODFW) 1991). Populations also decrease in size and density from the Mendocino National Forest south to Point Reyes, California, and from the Klamath province east to the area of contact with the California subspecies in the Sierra Nevada Range (Gould pers. comm.).

Most of the present population of owls is found in the Cascades and Klamath provinces in Oregon, and in the Klamath and Coast Range provinces in northwestern California (Advanced Sciences Inc. 1989, Beak Consultants 1989, Brown 1989, Diller 1989, Irwin et al. 1989c, Kerns 1989a and 1989b, Pious 1989, ODFW 1991, WDW 1991). Distribution of remaining habitat is similar to the present distribution of spotted owls.

More than 86 percent of currently known pairs of owls has been observed on federally managed lands. The distribution of these pairs varies widely by land ownership, state, and physiographic province (Table 2.3). Although inventories are least complete in California, about 30 percent of the habitat and population of spotted owls may occur in the Coast Range (Gould pers. comm.).

Only population data gathered during a 5-year period were analyzed during the development of the recovery plan because they may provide more reliable estimates of actual numbers than longer cumulative periods or single-year counts, given the rapidly changing quantity and quality of habitat. It is also the period with the most intense inventories, and is within the average life span of the species (about 8 years). Depending on availability of data, the period used was either 1986 through 1990 or 1987 through 1991 (see Table 2.3).

Inventories from 1987 through 1991 indicate a total of about 3,500 known pairs of northern spotted owls in Washington, Oregon, and northern California (Table 2.3). This number is a minimum estimate of the true population size. The actual number of spotted owls remaining is unknown.

3. Significant Threats to the Northern Spotted Owl

Table 2.4 provides a summary of significant threats to northern spotted owl populations by physiographic province. Threats were characterized as follows:

Severe: The problem poses a severe threat to the population at the current time or will pose such a threat within the next several generations. The likely consequence is failure to maintain a population distrib-

Table 2.3. Estimated spotted owl habitat and number of pairs of spotted owls located during a 5-year period on all lands in Washington, Oregon, and California.

Landowner or Agency[a]	Estimated Acres of Spotted Owl Nesting, Roosting, and Foraging Habitat by Timber Capability: Reserved[b]	Unsuitable for Harvest[c]	Suited for Harvest	Total Acres	Owl Pairs: Reserved	Non-reserved[d]	Totals
FS, Washington	500,024	804,000	747,000	2,051,024	56	417	473[f]
FS, Oregon	389,974	1,058,000	1,447,000	2,894,974	89	1,242	1,331[f]
FS, California	304,268	519,000	305,000	1,128,268	64	550	614[f]
BLM, Oregon	158,000	—	873,472	1,031,472	1	540	541[e]
BLM, California	13,000	—	6,000	19,000	0	11	11[e]
NPS, Washington	480,000	—	—	480,000	31	0	31[e]
NPS, Oregon	50,000	—	—	50,000	4	0	4[f]
NPS, California	40,000	—	—	40,000	2	0	2[e]
Indian lands, Washington	NA	NA	257,000	257,000	0	51	51[f]
Indian lands, Oregon	NA	NA	54,000	54,000	0	18	18[f]
Indian lands, California	NA	NA	32,000	32,000	0	28	28[f]
FWS, Washington	1,700	NA	5,000	6,700	0	0	0[f]
FWS, Oregon	4,100	NA	NA	4,100	0	0	0[f]
WDNR	NA	NA	NA	NA	0	33	33[f]
WDW	0	NA	5,000	5,000	0	0	0[f]
State parks, Washington	2,000	0	0	2,000	0	0	0[f]
Cities of Seattle, Tacoma, Washington	0	0	1,500	1,500	0	0	0[f]
ODF	0	NA	77,200	77,200	0	30	30[f]
State parks, Oregon	8,000	0	0	8,000	2	0	2[f]
Counties and cities, Oregon	NA	NA	NA	NA	1	0	1[f]
CDF	NA	NA	NA	NA	0	4	4[e]
State parks, California	56,000	0	0	56,000	0	10	10[e]
BLM/TNC, California	6,500	0	0	6,500	0	0	0[e]
NAS, California	600	0	0	600	0	0	0[e]
Private, California	NA	NA	NA	NA	NA	235	235[e]
Private, Oregon	NA	NA	NA	NA	0	50	50[f]
Private, Washington	NA	NA	NA	NA	0	31	31[f]
Totals	**2,014,166**	**2,381,000**	**3,810,172**	**8,205,338**	**250**	**3,250**	**3,500**

NA = Reliable estimates not available.
[a]Information obtained from landowners or state wildlife agencies.
[b]Withdrawn from timber harvest (e.g., wilderness, national park, research natural area).
[c]Lands unsuited for timber production because of allocation to other uses by land management plans, or technically unsuited for timber production because of soils problems or difficulty of regeneration.
[d]Owl pairs that are not on lands not withdrawn from timber harvest or that are on lands withdrawn on an interim basis.
[e]Five-year survey period = 1986-1990.
[f]Five-year survey period = 1987-1991.
FS = U.S. Forest Service
BLM = U.S. Bureau of Land Management
NPS = National Park Service
DNR = Washington Department of Natural Resources
WDW = Washington Department of Wildlife
ODF = Oregon Department of Forestry
NAS = National Audubon Society
TNC = The Nature Conservancy
CDF = California Department of Forestry and Fire Protection
Note: Numbers used in this table contain updates that were not available for the mapped data used in the geographic information system (GIS). Numbers cited elsewhere in the document were derived from the GIS and are not identical to numbers in the table.

uted across the range of ecological conditions in the province and the significant reduction of linkages and demographic support to adjacent provinces.

Moderate: The threat is not severe at the present time but would be expected to become severe within the next 10 generations if corrective measures are not undertaken. In most cases, these corrective measures will have to include actions to reverse present conditions and trends.

Low: The threat to the population is currently low and is expected to remain low as long as conservation measures are undertaken.

Unknown: Inadequate information currently exists to assess the threat. Not all threats are equally important, and no attempt was made to assign them weights. Comparisons between provinces cannot be based simply on the number of threats that fall in specific categories, e.g., the number of threats rated severe or moderate.

Low Populations. Small populations are vulnerable to extinction from a number of causes. Random fluctuations in environmental conditions (environmental stochasticity) and age and sex structure of populations (demographic stochasticity), along with potential loss of genetic variability (genetic stochasticity) are most likely to influence small populations.

Declining Populations. Population trends for northern spotted owls have been difficult to estimate because many of the adult and subadult birds are probably nonterritorial and difficult to detect on surveys. These "floaters" may wait for several years for a territory to become available before they pair and begin reproducing. If a population is declining, the number of territorial birds is likely to remain nearly constant as long as floaters remain, because territorial birds that die are replaced rapidly from the pool of floaters. Thus, territorial birds are the only segment of the population that can be monitored effectively, but trends in this segment of the population do not necessarily provide an accurate estimate of trends in the overall population.

One way to solve this problem is by analyzing birth and death rates. These rates then can be used to calculate whether the population is declining. The analyses, because they depend on how birth and death rates vary with age, are often complex. The underlying principle, however, is simply that the birth rate equals the death rate in a stable population. If the birth rate is less than the death rate, then population size declines.

The 1990 Status Review (USDI 1990) provided estimates of the rate of population change for two populations, one in northern California and one in southern Oregon. Both populations were shown to be declining. By the fall of 1991, data from 2 more years were available from these areas, and data were also available from three other study areas (Figure 2.3).

At the request of the Recovery Team, a group of 12 researchers was convened at Colorado State University to analyze this new information. The results indicated that all five populations declined from 1985 to 1991 (Table 2.5). The estimated rates of decline varied from 7 to 16 percent and averaged about 10 percent. The analyses also suggested that the rate of decline may be increasing. Details of the analysis are summarized in Appendix C. These new estimates reinforce the widely held belief that populations of spotted owls are declining throughout all or most of their range.

Limited Habitat. Throughout much of the range of the northern spotted owl, habitat is highly fragmented and is resulting in decreased owl productivity and

Table 2.4. Significant threats to the owl, by physiographic province (S = Severe, M = Moderate, L = Low, U = Unknown).

	Threats				
Ptovince	Low Population	Declining Population	Limited Habitat	Declining Habitat	Distribution
Eastern Washington Cascades	M	M	M	M	M
Western Washington[a] Cascades (South)	M	M	M	S	M
Western Washington Cascades (North)	S	U	S	S	S
Olympic Peninsula	S	M	M	M	M
Western Washington Lowlands	S	S	S	S	S
Oregon Coast	S	S	S	S	S
Western Oregon Cascades	L	M	L	M	L
Eastern Oregon Cascades	M	U	M	M	S
Klamath[b] (Oregon)	L	S	L	M	L
Klamath [b] (California)	L	M	L	M	L
California Cascades	S	S	S	M	S
California Coast	L	M	M	M	M

[a]Western Washington Cascades province divided into north and south portions to reflect differences in severity of threats.
[b]Klamath province includes portions of Oregon and California, thus threats are shown by state.

Province	Isolation	Predation	Competition	Conservation[c] Measures	Natural Disturbance
	Threats				
Eastern Washington Cascades	M	U	U	-	S
Western Washington[a] Cascades (South)	M	U	U	-	L
Western Washington Cascades (North)	S	U	U	-	L
Olympic Peninsula	S	M	U	-	S
Western Washington Lowlands	S	S	U	-	M
Oregon Coast	M	S	M	-	M
Western Oregon Cascades	L	M	M	-	L
Eastern Oregon Cascades	M	U	L	-	S
Klamath[b] (Oregon)	M	M	M	-	M
Klamath[b] (California)	M	L	M	-	M
California Cascades	M	L	M	-	L
California Coast	S	L	M	-	L

[c]Because of rapidly changing conservation measures, it is difficult to assess this threat, although it remains significant over much of the range of the northern spotted owl. See text for further discussion.

Table 2.5. Results of surveys for spotted owls, great horned owls, and barred owls in the range of the northern spotted owl. (Number of individual owls is shown in parentheses.)

Location/Province	Dates	Method of Enumeration	Spotted Owls	Great Horned Owls	Barred Owls	Sources
Southwest British Columbia	1985-1988	Responses to spotted owl calls from different sites	14	—	57	Dunbar et al. 1990.
Western Washington	1982, 1983	Responses to spotted owl calls	102	—	11	Hays et al. 1989.
Ross Lake Drainage, North Cascades National Park, Washington	1987	Responses to spotted owl calls	0	1	11	Bjorklund and Drummond 1987.
Wilderness in Wenatchee and Okanogan National Forests and North Cascades National Park, Washington	1989	Responses to spotted owl calls, some other owl calls, and "volunteer" responses	8	5	12	Irwin et al. 1989a.
Washington Cascades	1986-1989	Birds on 122-square-mile study area	(16)	(25)	(31)	Hamer et al. 1989.
Hoh-Clearwater, Olympic Peninsula, Washington	1988, 1989	Responses to spotted owl calls and "volunteer" responses	389	274	5	Anthony and Cummins 1989.
Western Washington Lowlands	1987, 1988	Responses to spotted owl calls, some other owl calls, and "volunteer" responses	58	279	17	Irwin et al. 1989b.
Washington Eastern Cascades (Yakima Reservation)	1991	Responses to spotted owl calls	58 (21)	70	3	Hanson, unpubl. data
Oregon Western Cascades	1989, 1990	Responses to spotted owl and great horned owl calls	294 (161)	193 (95)	27 (16)	Johnson, and Meslow unpubl. data
Central Oregon Coast Range	1991	Responses to spotted owl calls; 6 percent of 38,000 acres of state land in trees > 75 years	0	27 (10)	0	ODFW unpubl. data
Oregon Coast Range	1990, 1991	Responses to spotted owl and great horned owl calls	47 (18)	341 (118)	0 (0)	McGarigal, unpubl. data

dispersal success, as well as increased mortality. Individual pairs are becoming isolated in significant portions of most provinces. Provinces with 20 percent or less of potentially suitable habitat currently in suitable condition generally are considered to be under severe threat, and those with less than 40 percent in suitable condition generally are considered to be under moderate threat (Bart and Forsman 1992).

Declining Habitat. In the near future, continued loss of habitat at recent rates (1 to 2 percent per year) will likely accelerate current population declines. If habitat is already below critically low levels, the continued loss of potential habitat would further reduce management options and lengthen the time required to achieve recovery.

Distribution of Habitat or Populations. Within many provinces, populations and habitat are poorly distributed, so that owls are no longer present across the full range of ecological conditions (e.g., elevation zones) and populations are

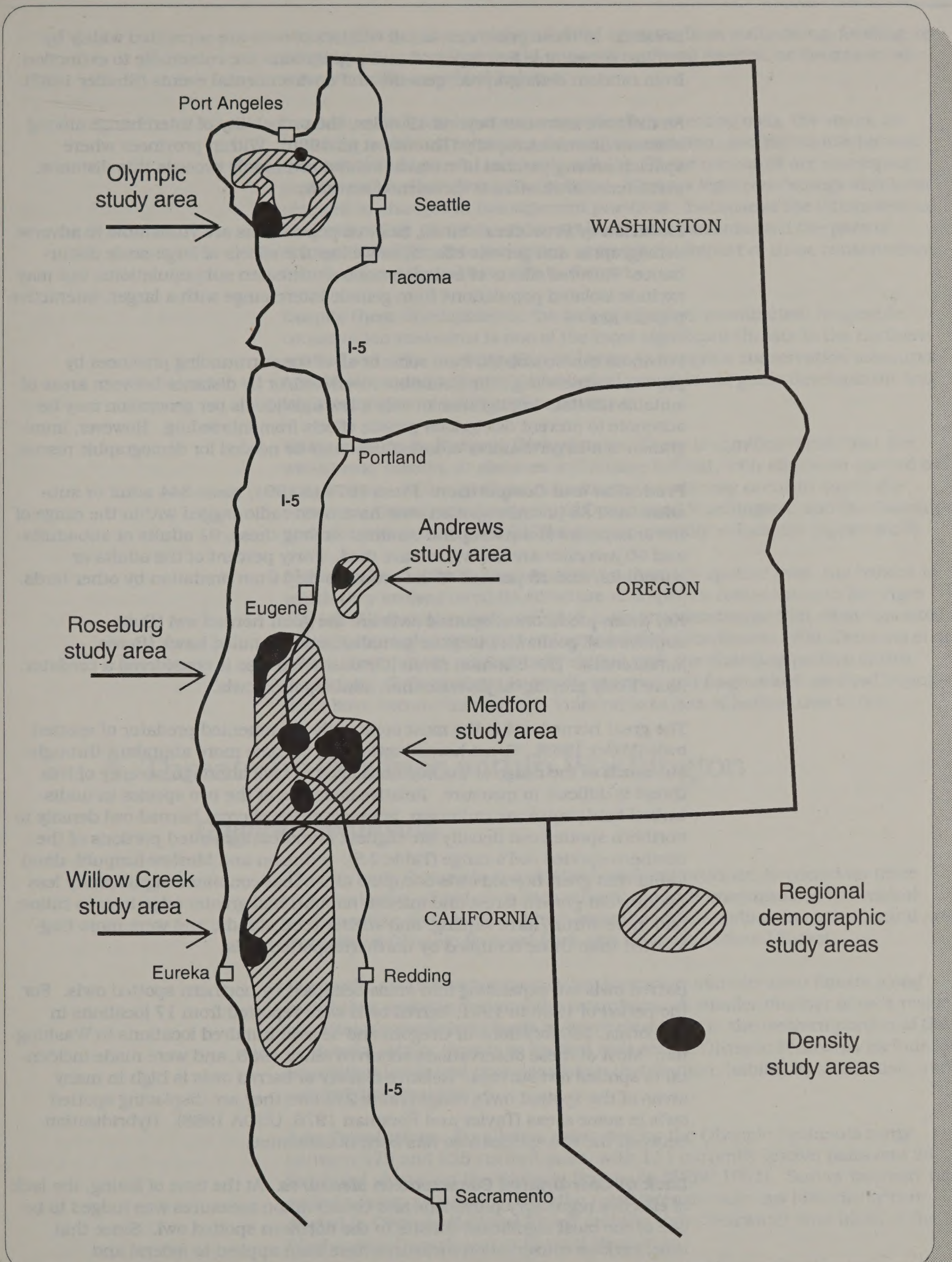


Figure 2.3. Demographic study areas.

isolated. In these provinces, small clusters of owls are separated widely by habitat unsuitable for dispersal, and populations are vulnerable to extinction from random demographic, genetic, and environmental events (Shaffer 1987).

As distance increases beyond 12 miles, the probability of interchange among clusters decreases rapidly (Thomas et al. 1990). Within provinces where spacing among patches of suitable habitat commonly exceeds this distance, persistence of clusters is threatened severely.

Isolation of Provinces. Small, isolated populations are vulnerable to adverse demographic and genetic effects, as well as the effects of large-scale disturbance. Adverse effects of isolation not only threaten subpopulations, but may exclude isolated populations from genetic interchange with a larger, interactive population.

Provinces can be isolated from some or all of the surrounding provinces by physical barriers (e.g., the Columbia River) and/or by distance between areas of suitable habitat. Immigration of only a few individuals per generation may be adequate to prevent deleterious genetic effects from inbreeding. However, immigration of a larger number of individuals may be needed for demographic rescue.

Predation and Competition. From 1975 to 1991, some 344 adult or subadult, and 85 juvenile spotted owls have been radio-tagged within the range of the subspecies (Johnson pers. comm.). Among these, 91 adults or subadults and 60 juveniles are known to have died. Forty percent of the adults or subadults, and 25 percent of the juveniles died from predation by other birds.

Key avian predators of spotted owls are the great horned owl (*Bubo virginianus*), goshawk (*Accipiter gentalis*), and red-tailed hawk (*Buteo jamaicensis*). The common raven (*Corvus corax*) also is considered a predator, more likely preying on juvenile than adult spotted owls.

The great horned owl is the most commonly documented predator of spotted owls (Miller 1989). Great horned owls have become more abundant throughout much of the range of the northern spotted owl, although severity of this threat is difficult to measure. Relative densities of the two species in undisturbed landscapes are unknown, however ratios of great horned owl density to northern spotted owl density are highest in more fragmented portions of the northern spotted owl's range (Table 2.5). Johnson and Meslow (unpubl. data) found that great horned owls occupied areas that contained significantly less mature/old-growth forest and interior habitat; had greater edge-to-area ratios; had more shrub/forb, sapling, and shelterwood stands; and were more fragmented than those occupied by northern spotted owls.

Barred owls are expanding into areas occupied by northern spotted owls. For the period of 1980 to 1991, barred owls were reported from 17 locations in California, 260 locations in Oregon, and several hundred locations in Washington. Most of these observations occurred since 1985, and were made incidental to spotted owl surveys. Relative density of barred owls is high in many areas of the spotted owl's range (Table 2.5) and they are displacing spotted owls in some areas (Taylor and Forsman 1976, USDA 1988). Hybridization between the two species also has been documented.

Lack of Coordinated Conservation Measures. At the time of listing, the lack of effective regulatory provisions and conservation measures was judged to be one of the most significant threats to the northern spotted owl. Since that time, various conservation measures have been applied to federal and nonfederal lands. The Endangered Species Act prohibits actions that will result in taking owls, regardless of the land ownership on which the taking

occurs. The act also prohibits federal agencies from authorizing, funding, or carrying out action that would jeopardize a listed species, or destroy or adversely modify its critical habitat.

In addition to federal measures specifically protecting owls, the states are pursuing additional measures for owl conservation, and for wildlife habitat conservation in general (see section II.C.). These measures are developing rapidly and further change is expected. Various legal proceedings also have resulted in changes in management practices. Because of the differences in land ownership patterns, state regulatory mechanisms, and the pace of change, it is difficult to accurately quantify the impact of these conservation measures and the relative risk to the owl.

Despite these developments, the lack of effective, coordinated, rangewide conservation measures is one of the most significant threats to the northern spotted owl. The recovery plan will serve to integrate conservation measures now in place, and will provide biological principles to guide development and implementation of additional measures.

Vulnerability to Natural Disturbance. There is significant risk that fire, windthrow, insects, or diseases will reduce habitat, with effects on spotted owl populations. Although these disturbance events may occur in any of the provinces, the eastern Cascades of Oregon and Washington, and the Cascades and Klamath provinces of California are especially vulnerable (Appendix F).

Although fire currently may represent a threat to spotted owls, the habitat in which they evolved owed its structure and species composition to fire (Agee 1991a). Historically, owls occupied a dynamic landscape that often consisted of large areas of burned and unburned forest (Henderson 1990, Teensma et al. 1991). Populations undoubtedly shifted with the changing pattern of this landscape. Today habitat is greatly reduced and fragmented, and owl populations have become increasingly vulnerable to loss of habitat due to fire.

4. Threats by Province within Washington

Olympic Peninsula

The Olympic Peninsula is a relatively isolated province, bordered on three sides by bodies of water. A high mountain range encompasses the central portion of the peninsula and high-elevation ridges radiate from the central area throughout Olympic National Park and Olympic National Forest.

Currently, spotted owls generally are located in mid-elevation forests along major river systems draining the mountains. A smaller number of owls reside on primarily nonfederal lands at lower elevations in the western portion of the peninsula. Major threats to spotted owls on the Olympic Peninsula include low population levels and poor population distribution, habitat loss, isolation, and natural disturbances.

Low Populations. Population estimates for the Olympic Peninsula range between 175 and 225 current pairs, with 111 currently known pairs and 26 territorial singles on the Olympic Peninsula (WDW 1991). Survey intensity has varied among ownerships, with the most intensive surveys historically conducted in Olympic National Forest and the Hoh-Clearwater land block of the Washington Department of Natural Resources.

Private and other state lands received little survey effort until summer 1991, when more intensive survey efforts were undertaken. Currently, activity

centers for 30 to 35 spotted owl territories are located on state or private lands on the Olympic Peninsula, although additional owls with activity centers on federal lands likely utilize state and private lands. Most of the spotted owl sites located on nonfederal lands occur in the western portion of the province, north of the Quinault Indian Reservation.

Because of the roadless nature of Olympic National Park, spotted owl surveys are extremely difficult and only a portion of the park has been surveyed. Past population estimates for the park have been based largely on densities of owls in demographic study areas in adjacent Forest Service lands and Landsat analysis of amounts and distribution of suitable habitat within the park (Thomas et al. 1990). Estimates vary between 60 and 80 pairs in Olympic National Park. Approximately 45 distinct territories have been located in the interior portion of the park, with an additional eight territories in the narrow coastal portion.

The current estimated population of 200 pairs on the peninsula has a low likelihood of persistence during the next 100 years unless measures are taken to resolve the existing threats.

Declining Populations. High rates of habitat loss on nonfederal and national forest lands undoubtedly are reflected in spotted owl population declines. Since World War II, old-growth forest in Olympic National Forest has declined 76 percent (Morrison 1990). Large areas of habitat loss on the Olympic Peninsula include the Olympic National Forest Shelton Sustained Yield Unit, the Quinault Indian Nation, and the area of state and private ownership west of Forks and north to the Straits of Juan de Fuca. Northern spotted owls once inhabited these lower elevation areas, likely in high densities. Reproductive success has been highly variable in past years, and continued monitoring will be required for adequate trend assessment. However, populations in the Olympic Peninsula demographic study area are declining nearly 12 percent annually (Appendix C.).

Limited Habitat. Suitable habitat is highly fragmented at lower elevations on the Olympic Peninsula. Past habitat loss has likely resulted in low numbers of spotted owls on Indian, state, and private lands. Many owl sites on national forest lands are located in highly fragmented areas, especially along the southern portions of the Quinault and Hood Canal Ranger Districts. Habitat within Olympic National Park is found in relatively large, intact drainages broken by high, rocky, and snow-covered mountains. Individual owl pairs along the Olympic National Park coastal strip have become relatively isolated from the remaining spotted owls in the interior peninsula. Effects of habitat loss on spotted owl productivity, dispersal, and turnover on the peninsula are not well known.

Declining Habitat. In the near future, the expected net rate of habitat loss under current management will jeopardize significantly the potential for recovery on nonfederal lands. Habitat has been reduced to critical levels on national forest lands and is declining. Habitat is unchanged and in good condition on suitable portions of national park lands.

Distribution of Habitat and Population. Suitable habitat in the interior peninsula is shaped largely like a doughnut, with the center or "hole" consisting of high-elevation, nonforested areas of unsuitable habitat. Remaining habitat and owls on the Olympic Peninsula are located centrally around this "doughnut hole" within the higher-elevation areas of Olympic National Park and Olympic National Forest. Large areas of recently logged, low-elevation lands are occupied by scattered, relatively isolated pairs of spotted owls in remaining patches of older forest. This central clustering restricts the distribu-

tion of spotted owls to a portion of the province, generally at higher elevations. The long-term stability is unknown for these populations that once inhabited a wide range of ecological conditions, but are limited now to high-elevation habitat.

Predation and Competition. Levels of predation by great horned owls and competition with barred owls and northern goshawks on the Olympic Peninsula are not understood well. Barred owls are present on the peninsula, but no evidence of competition has been documented. Predation by great horned owls may have increased over historic levels with an associated decrease in the survival of northern spotted owls.

Province Isolation. The Olympic Peninsula province is isolated on three sides by coastline; the Pacific Ocean to the west, the Straits of Juan de Fuca to the north, and Hood Canal to the east. To the south, timber harvest in the lowlands of western Washington virtually has eliminated spotted owls. Currently, approximately 60 miles separate owl subpopulations on the Olympic Peninsula and subpopulations in the western Cascades. Distance between currently known reproductive pairs is approximately 75 miles. Isolation may decrease the number of successfully dispersing juveniles and inhibit movement of adults among populations (Thomas et al. 1990).

There is little or no dispersal between this and other populations, and demographic rescue would be unlikely in the event of a population decline on the Olympic Peninsula. Following such a decline, inbreeding could become a concern.

Offsetting a demographic decline on the peninsula or restocking a population areawhere spotted owls have become locally extirpated due to catastrophic or stochastic events would be assisted by demographic connectivity between spotted owls on the Olympic Peninsula and those in other provinces. This likely would require establishment of groups of breeding pairs in the western Washington lowlands province.

Vulnerability to Natural Disturbances. Wind is the dominant disturbance factor along the western coast of the peninsula and as far as 20 to 30 miles inland. Historic stand-replacing wind events occurred in 1921 and 1962 (Appendix F). Logging within the past 30 years has resulted in increased fragmentation on Forest Service, state, and private lands. Exposed forest edges are much more susceptible to wind damage than are relatively unfragmented patches. The potential is high for a large-scale wind event to adversely affect spotted owl habitat in this region (Appendix F). Fire is also a significant threat on the Olympic Peninsula, particularly in the eastern portion. Recent fires, such as the Forks Burn, were stand-replacement events that eliminated significant tracts of spotted owl habitat. Agee (1991b) suggests that under a worst case scenario, wind and fire could reduce the capability of the Olympic peninsula to support spotted owl pairs by up to 30 percent during the next 100 years.

Western Washington Lowlands

Ownership in this province is largely nonfederal and includes major urban, industrial, and agricultural areas. Most forestland is owned by the State of Washington or large industrial timber corporations. This province includes the Puget Trough and southwest Washington physiographic provinces as delineated by Franklin and Dyrness (1973) because these regions show similarities in spotted owl densities, land ownership patterns, and ecological conditions.

Southwest Washington occupies a key position on the landscape. It is the only area where connectivity could be reestablished with the currently isolated population of northern spotted owls on the Olympic Peninsula. Major threats to the few currently known spotted owls in the western Washington lowlands province include low numbers, local isolation, habitat loss, and poor distribution.

Low Populations. There has been considerable concern for spotted owls in this geographic region (Thomas et al. 1990, USDI 1990). Currently three pairs and one territorial single are known in the province. In terms of population stability and structure, spotted owls essentially have been eliminated.

Limited Habitat. Forestlands in the western Washington lowlands were logged early in the settlement of the state, and a considerable area was converted to urban, industrial, and agricultural lands. Historical observations of spotted owls are documented from the early communities of Seattle and Tacoma (WDW 1991). Habitat conversion has been extensive from Tacoma north to the Canadian border, and likely will increase significantly during the next 100 years as human populations increase. Extensive forestlands still remain in the southwest portion of the state. Many of these lands already have been logged twice.

Spotted owl habitat has been reduced greatly during the past 60 to 80 years. Late-successional forest currently remains in relatively small, scattered parcels, seldom more than a few hundred acres in size. The few existing spotted owls are located in these patches surrounded by young forest or are inhabiting younger forest stands that have retained snags and/or dead, decaying logs from previous harvest or natural disturbance.

Declining Habitat. The little suitable habitat remaining within the province likely will be reduced further unless immediate action is taken. Of equal or greater concern is the rate of harvest of mature forest, which may serve as the potential foundation for restoration of owl habitat in the province.

Province Isolation. Spotted owls within the province are extremely isolated from one another, with little opportunity for interchange among territories. The province currently does not provide for demographic interchange with any of the neighboring provinces. Providing for that interchange will require developing subpopulation centers, essentially by growing habitat for a number of pair clusters.

Predation and Competition. Predation by great horned owls may be a threat to the few remaining owls or to development of owl clusters in the future. Recent surveys suggest that great horned owls are numerous (Table 2.5).

Vulnerability to Natural Disturbances. Portions of the province along the Pacific Coast may be susceptible to wind damage, similar to the western portion of the Olympic Peninsula. Wind and fire are potential threats to the few remaining spotted owls in the province.

Western Washington Cascades

The western Washington Cascades province lies west of the Cascade Crest from the Columbia River north to the Canadian border. Ownership is primarily federal, although state, private, and municipal ownerships play important roles for spotted owls in several areas. The province consists of three geographic areas; the northern Cascades (Interstate 90 to the Canadian border), the Interstate 90 (I-90) corridor (north of Mt. Rainier to I-90), and the southern Cascades (Mt. Rainier south to the Columbia River). Significant topographic

differences occur in the northern and southern portions of the province. The northern area is dominated by high mountains and ridges unsuitable for spotted owls and lower valleys with suitable spotted owl habitat. The resulting landscape pattern is a mosaic of alternating valleys of suitable habitat and unsuitable ridges, a naturally fragmented environment for spotted owls. The southern portion is much less dominated by mountainous areas, and spotted owl habitat is more continuous, although still highly fragmented by past timber harvest.

Low Populations. The currently known spotted owl population includes approximately 200 pair and single owl territories (WDW 1991). This number will change as additional areas are surveyed. Spotted owls are found throughout the province, although at lower densities in the northern portion and in the I-90 corridor area. The I-90 corridor is an area of checkerboard ownership lands (federal with state, private, or municipal) that has been harvested heavily in the past 20 to 30 years. Approximately 20 spotted owl territories occur in the I-90 corridor in the western Washington Cascades province. In the northern region, in only 22 territories are known to have produced young successfully since 1986 (WDW 1991). In addition, owls only two territories in the I-90 corridor have produced young successfully since 1986. Reproductive success has been higher in the southern portion of the province.

Limited Habitat. Current spotted owl habitat generally is located at higher elevations, predominantly on national forest lands. Much of the accessible, low-elevation habitat has been logged previously, and current stands that have regenerated after harvest generally are less than 80 years old.

Few blocks of old-growth forest remain on state, private, and municipal lands. Most of the currently known spotted owls on these lands (outside of checkerboard ownership lands) inhabit patchwork mosaics of remnant old-growth stands that survived historic forest fires within larger naturally regenerated second-growth stands. The I-90 corridor has been harvested heavily within the past 20 years, as has the area known as the Mineral Block in the Gifford Pinchot National Forest.

Declining Habitat. Spotted owl habitat in the province has declined significantly in the last 30 years. During this time the proportion of old-growth that was potential spotted owl habitat has decreased from about 60 percent to about 40 percent of the area of the Mt. Baker-Snoqualmie National Forest, with similar decreases from about 40 percent to 30 percent for the Gifford Pinchot National Forest (Henderson 1990). The relatively low proportions of old-growth on the Gifford Pinchot National Forest resulted from the Yacolt Burn of 1902 and the eruption of Mount St. Helens in 1980, as well as logging.

In recent years, habitat decline has been most severe, proportion in the I-90 corridor and the Mineral Block of the Gifford Pinchot National Forest. Habitat surrounding 38 randomly selected spotted owl management areas on the Mt. Baker-Snoqualmie and Gifford Pinchot National Forests was analyzed in 1984 (Allen et al. 1989). The average proportion of suitable habitat within 1.5 and 2.1 miles of the center of these areas varied between 49 and 55 percent of the total area at that time. Analysis of information presented in the 1991 Forest Service Timber Sale Biological Assessment indicates that the average proportion of suitable habitat within 1.8 miles of spotted owl territories was near 40 percent (Hays pers. comm.). The difference between these habitat estimates during the past 7 years is an indication of severe habitat decline in a relatively short period of time. In the near future, the expected net rate of habitat loss without protective measures for the spotted owl will significantly decrease the potential for recovery on both federal and nonfederal lands.

Distribution of Habitat and Populations. There are several concerns about the distribution of habitat and owls in the western Washington Cascades province. In the northern portion, no large clusters of spotted owls currently occur. Much of the habitat in lower elevation areas has been eliminated, and interchange among remaining individuals or small clusters of spotted owls likely is inhibited by nonforested, high-elevation ridges, peaks, and glaciers.

As in the northern portion, no large clusters of spotted owls currently occur in the I-90 corridor. Distribution concerns are primarily with north-to-south interchange of dispersing young and adults. With greatly reduced levels of suitable spotted owl habitat in this region, there is significant isolation of the northern and southern portions of spotted owl populations in the Washington Cascades. North-to-south interchange is further restricted by narrowing of federal ownership in the I-90 corridor area.

In the southern portion of the province, two significant distributional concerns occur. Spotted owl populations in Washington and Oregon are separated naturally by the Columbia River. Historically, spotted owls probably were located along the northern and southern banks of the Columbia River. Logging and urban development in lowland areas of western Washington and Oregon have resulted in a restricted area of interchange, or "bottleneck" between spotted owls in both states. Currently, interchange between spotted owl populations in the two states likely occurs only in a 18- to 20-mile zone in the Columbia Gorge, if at all. Primary ownership on the Washington side of the gorge includes state, private, and federal lands. It is unknown to what degree spotted owls in the two states interact. State and private lands are important in addressing these distributional concerns in the I-90 corridor and the Columbia Gorge.

The northwest portion of the Gifford Pinchot National Forest represents another distributional concern. The Mineral Block is critical to potential genetic and demographic interchange between the Olympic Peninsula province and the western Washington Cascades province. Currently, 10 known spotted owl territories are located in this checkerboard ownership block. Nonfederal lands currently support spotted owls, and are important for long-term development of a stable subpopulation in this area.

Province Isolation. The two provinces that comprise the Washington Cascades are connected by contiguous habitat and owls in only a few high-elevation areas, such as Steven's, Snoqualmie, and White Passes. The extent of demographic interchange over these mountain passes is unknown. The northern portion of the province is virtually at the edge of the species' current range. Spotted owls in southern British Columbia are found in low numbers and densities, and are unlikely to provide demographic support to owls in northern Washington. The degree of province isolation in the Columbia River area is unknown. Spotted owls in the Washington Cascades probably are isolated demographically at present from owl populations on the Olympic Peninsula.

Vulnerability to Natural Disturbances. The eruption of Mount St. Helens eliminated a large forested region containing a number of spotted owls. The blast zone is similar in size to an area that might support a large cluster of 20 or more pairs of spotted owls as described by Thomas et al. (1990). A volcanic eruption of Mt. Baker, Mt. Rainier, Glacier Peak, or Mt. Adams could result in elimination of one or more conservation areas, and local isolation of subpopulation centers.

Eastern Washington Cascades

The eastern Washington Cascades province lies east of the Cascade crest from the Columbia River north to the Canadian border. Ownership is primarily federal and Indian lands, although some state and private lands are located in key areas in the province. Within the province are several important sub-areas for spotted owls. The northern portion includes the Okanogan National Forest, and Entiat and Chelan Ranger Districts of the Wenatchee National Forest. The central area stretches from north of the Wenatchee to Yakima, and includes the rest of the Wenatchee National Forest as well as the checkerboard ownership state and private lands (including the eastern portion of the I-90 corridor) and nonfederal lands adjacent to the national forest. The Yakima Indian Reservation also constitutes a sub-area, located south of the Wenatchee National Forest. The southern portion of the province is located south and west of the Yakima Indian Reservation, including portions of the Gifford Pinchot National Forest and mixed ownerships of state and private lands.

Low Populations. Population estimates for the eastern Washington Cascades province range between 250 and 300 current pairs (WDW 1991). There are approximately 160 known pairs in the region. Survey efforts have varied widely among ownerships, with more intensive surveys historically conducted on the Wenatchee and Okanogan National Forests. State, private, and Indian lands received varying degrees of survey effort until 1991, when more intensive survey efforts were undertaken.

Currently, activity centers for 30 spotted owl territories are located on state or private lands in the eastern Cascades. A number of spotted owls with activity centers located on federal lands also likely uses state and private lands, primarily as a result of checkerboard ownership patterns. Approximately 20 spotted owl territories occur in the northern sub-area. These territories largely affect only federal ownership. Approximately 24 known territories occur on the Yakima Indian Reservation. Estimates of current numbers on the Yakima Indian Reservation range up to 50 pairs (Hansen pers. comm.).

Limited Habitat. In general, habitat in the eastern Washington Cascades is in somewhat better condition than that of the western Cascades in Washington. In the I-90 Corridor, there is approximately 10 to 15 percent more habitat in the eastern Cascades than in the western Cascades. This difference may have significant effects on occupancy rates and reproductive success of spotted owls (Bart and Forsman 1990). As in other provinces, much of the lower elevation habitats have been logged heavily but primarily with partial-harvest techniques.

Most spotted owl habitat in the eastern Washington Cascades is found in the Yakima Indian Reservation and four Ranger Districts in the Wenatchee National Forest: Naches, Cle Elum, Leavenworth, and Lake Wenatchee (including the checkerboard ownership nonfederal lands). Much of the region is dominated by high-elevation mountains and ridge-tops that are not suitable spotted owl habitat. These topographic restrictions shift emphasis for conservation to low-elevation, mixed conifer forests and smaller clusters of spotted owls.

Distribution of Habitat and Populations. Spotted owls and habitat are poorly distributed in the portion of the Okanogan National Forest within the range of the species, the Chelan and Entiat Ranger Districts, nonfederal lands between the Wenatchee National Forest and the Yakima Indian Reservation, and the mixed-ownership southern portion of the province. Recovery measures emphasizing habitat development may be needed in these areas to provide for subpopulation centers throughout the province.

Province Isolation. The eastern Washington Cascades province is isolated somewhat from other spotted owl subpopulations on northern, southern, and western boundaries. The two provinces that comprise the Washington Cascades are connected by contiguous habitat and owls in only a few areas. The northern portion of the province is virtually at the edge of the species' current range and the few spotted owls within this region are isolated from larger groups of owls south of Lake Chelan. Spotted owls in southern British Columbia are found in low numbers and densities, and are unlikely to provide demographic support to owls in northern Washington. The degree of province isolation in the Columbia River area is unknown.

Vulnerability to Natural Disturbances. There is a significant potential for large-scale fire in the eastern Washington Cascades province. There is a low probability that any conservation area created in the eastern Cascades of Washington will avoid stand-replacing wildfire over a significant portion of the landscape during the next century (Appendix F). As spotted owls in the province currently are clustered in a few key areas, fire poses a severe natural threat to population recovery. Similar to the situation in the western Cascades, volcanic eruptions of Mt. Adams, Mt. Rainier, or Glacier Peak could eliminate one or more conservation areas and increase within-province isolation of subpopulations.

5. Threats by Province within Oregon

Oregon Coast Range

The Oregon Coast Range province lies west of the Willamette Valley and extends along the coast from the Columbia River south to about the Coquille River. The province is characterized by generally low-elevation, productive forests in areas of high precipitation. Land ownership of the approximately 4.48 million acres in the Coast Range is 57 percent private, 13 percent Forest Service, 17 percent BLM, and 13 percent state (Figure 2.4a). Federal lands are represented by the Siuslaw National Forest and parts of the Salem, Eugene, Coos Bay, and Roseburg BLM Districts. Timber harvest and extensive wildfires have greatly reduced and fragmented spotted owl habitat. Threats to the owl population in this province are greater than those in any other Oregon province (Table 2.4).

Low Populations. The owl population within this province is extremely low, particularly in the northern three-fourths of the province. A total of about 325 pairs has been found within the last 5 years. Owls are poorly distributed within the province and exist at very low densities with many pairs isolated by more than 10 miles. Forty-five percent of the known spotted owl sites lie south of Highway 38, in the southern quarter of the province. Most spotted owl sites within the province have less than 40 percent suitable habitat within home range areas (USDI 1991a).

Most owl sites are located in the southern portion of the province and are associated with BLM lands. As a result of timber harvest on the interspersed BLM and private lands, the forest landscape is very fragmented.

The Elliott State Forest is a 93,000-acre block of state-owned land northeast of Coos Bay. Surveys in the Elliott State Forest in 1991 revealed 20 pairs and 18 single owls. These owls are of particular interest due to the age structure of trees within the forest. Sixty percent of the Elliott State Forest is composed of trees from 90 to more than 140 years of age (trees on the remaining area are

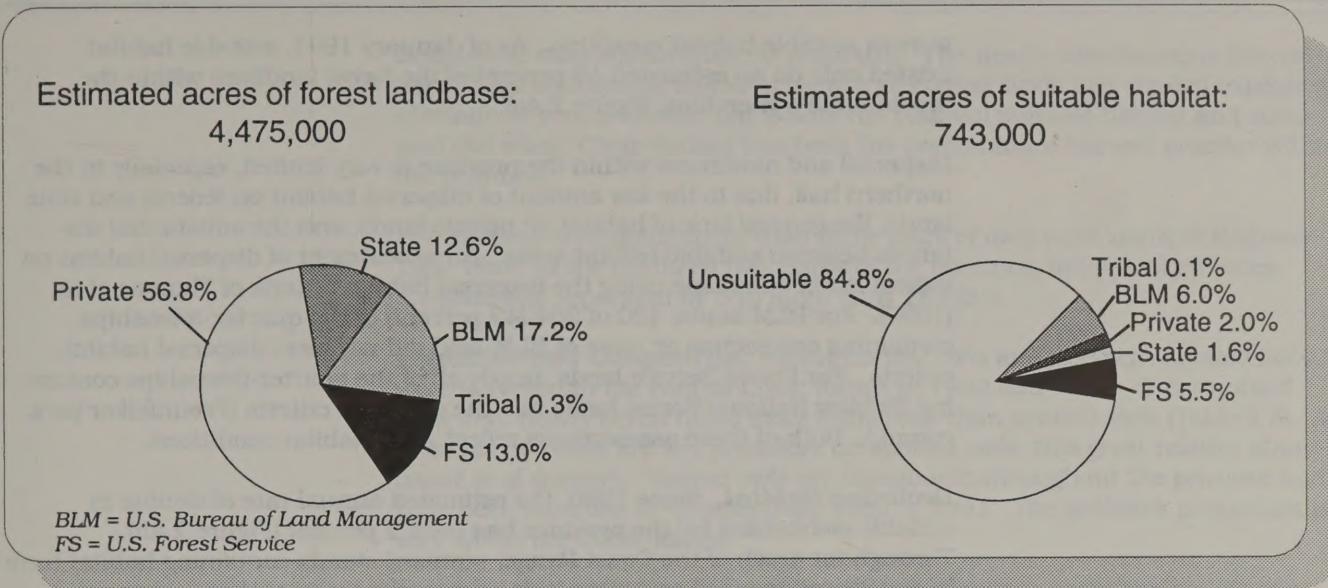


Figure 2.4a. *Land base and suitable habitat, Oregon Coast Range.*

less than 40 years of age). Research is needed to determine if the population of owls is self-sustaining. Owl populations elsewhere in the province are in significant decline.

Surveys for owls were conducted on 38,000 acres of state land in the central portion of the province (west of Corvallis) during 1990 and 1991. Only 6.1 percent of this state land (6,257 acres) contains trees older than 75 years of age; mean stand size is 26.2 acres (+sd 20.2; range 1 to 120 acres). Only one spotted owl response was noted in 1991, with that owl being from a site adjacent to, rather than within, state lands. Although these state lands likely supported owls in previous years, owls no longer exist in this landscape.

The Tillamook State Forest in the northern portion of the province contains 480,000 acres of forestlands, 3 percent of which currently support trees older than 80 years. Large fires in 1933, 1939, and 1945 burned a total of 345,936 acres. Subsequent reforestation has created a relatively homogeneous forest, with stands 30 to 50 years of age. Older forest stands outside of the burned area, now isolated due to timber harvest, contain the remaining owls and habitat. As of September 1991, 25 owl sites were present on state and federal lands north of Highway 18.

Declining Populations. Based on demographic data gathered in the Roseburg study area from 1985 to 1991, the finite rate of increase (lambda) for Coast Range study areas is 0.941 (Appendix C), indicating an annual population decline of about 6 percent.

Limited Habitat. Suitable habitat within the Oregon Coast Range is extremely limited and poorly distributed, especially north of Highway 38. Fragmentation of remaining habitat within this province is of significant concern and is due largely to timber harvest and land-ownership patterns. The lack of suitable habitat is particularly acute in the northern part where federal lands are virtually nonexistent. Habitat quantity and quality have been reduced severely due to: 1) extensive timber harvest, 2) fragmentation and isolation of remaining stands, and 3) catastrophic fires and the resulting salvage of live and dead trees. As of August 1991, only 37 percent of the federal lands (Neitro pers. comm., Mellen pers. comm.), 12 percent of the state lands (Johnson pers. comm.), and 3 percent of the private lands (Greber et al. 1990) in the province

were in suitable habitat condition. As of January 1991, suitable habitat existed only on an estimated 15 percent of the forest landbase within the province (all ownerships, Figure 2.4a).

Dispersal and movement within the province is very limited, especially in the northern half, due to the low amount of dispersal habitat on federal and state lands, the general lack of habitat on private lands, and the substantial distances between suitable habitat areas. An assessment of dispersal habitat on federal lands was made using the dispersal habitat criteria of Thomas et al. (1990). For BLM lands, 130 of 264 (49 percent) of the quarter-townships containing one section or more of BLM land did not meet dispersal habitat criteria. For Forest Service lands, nearly all of the quarter-townships containing Siuslaw National Forest lands met the dispersal criteria (Frounfelker pers. comm.). Both of these assessments reflect 1991 habitat conditions.

Declining Habitat. Since 1950, the estimated annual rate of decline in suitable owl habitat for the province has been 2 percent (Figure 2.4b). Throughout much of the Coast Range, remnant stands containing habitat have been reduced to small and often isolated parcels; many of these areas no longer support owls. The little suitable habitat remaining within the province will be further reduced without immediate action. Of equal concern is the rate of harvest of 60- to 80-year-old stands, which may serve as the foundation for restoration of owl habitat in the province.

Distribution of Habitat and Population. The remaining habitat within the province typically occurs as scattered pockets within a matrix of younger

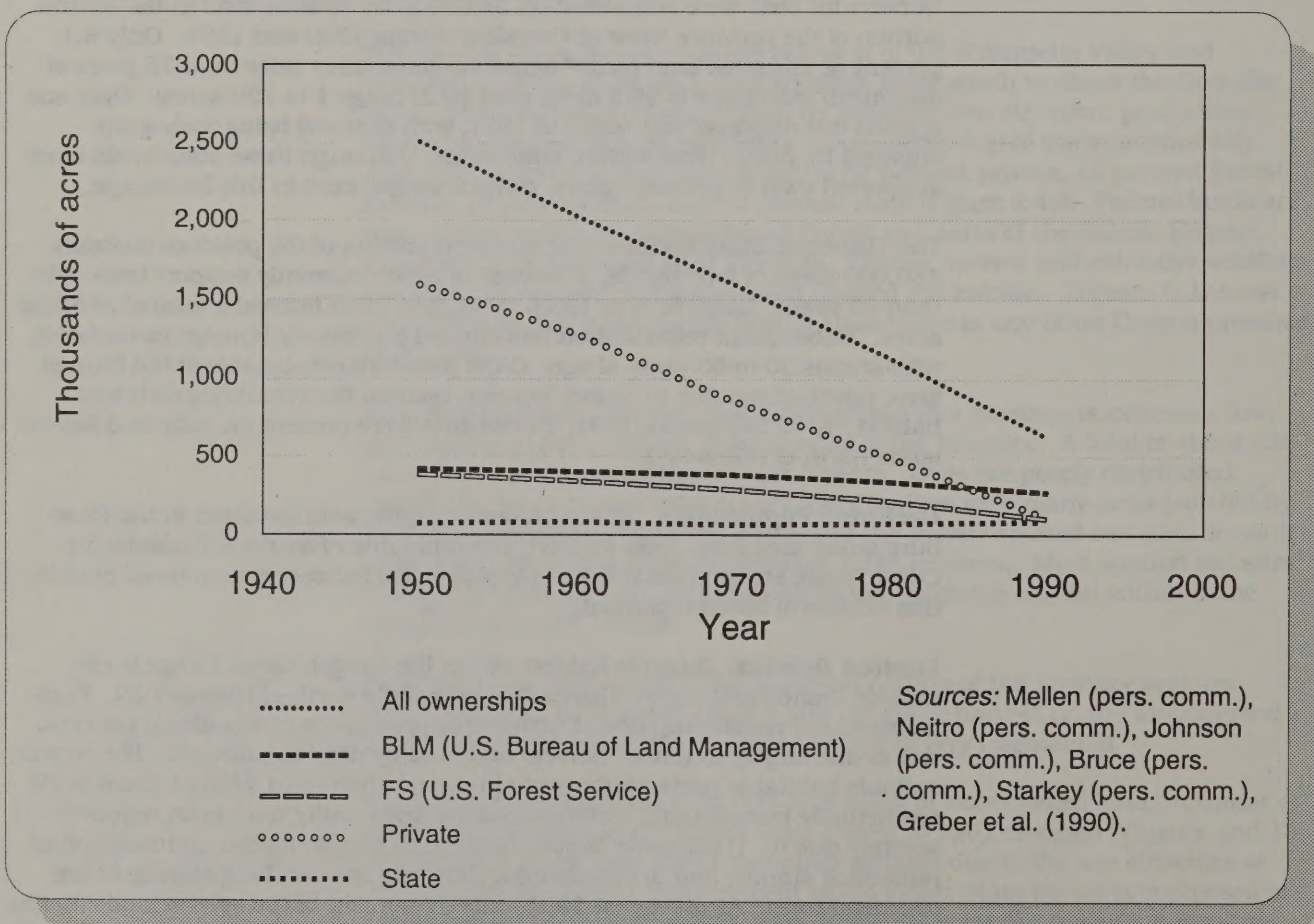


Figure 2.4b. *Trend in northern spotted owl habitat, Oregon Coast Range province.*

Douglas-fir stands (less than 50 years old). The nearly simultaneous harvesting of large contiguous blocks of industrial-owned lands has created expanses of relatively young forests that isolate the residual suitable habitat and occupied owl sites. Clear-cutting has been the predominant harvest practice within the province.

Few clusters containing more than three pairs of owls exist north of Highway 126. Here, in the northern two-thirds of the province, individual owl sites are generally separated by 3 to more than 15 miles.

Predation and Competition. Great horned owls and northern spotted owls were surveyed in the central Coast Range in 1990 and 1991. Great horned owls were nearly seven times more numerous than spotted owls (Table 2.5). As great horned owls are key predators on spotted owls, this great relative abundance is of concern. Barred owls are distributed throughout the province and have been recorded at 46 sites from 1980 to 1991. The goshawk population is very low in the Coast Range.

Province Isolation. The province is connected to the western Cascades province in Oregon through forested lands south of Eugene, and to the Klamath and western Cascades provinces south of Canyonville. These key linkage areas contain BLM and private lands in a checkerboard pattern. Due to past and present timber harvest on federal and intervening state and private lands, habitat is particularly limited. For example, BLM lands within 50 percent of the quarter-townships in this area do not contain owl habitat adequate for dispersal (i.e., do not meet the "50-11-40 rule" as described in Thomas et al. 1990). Therefore, the risk of isolation of the Oregon Coast Range province is high and will increase with additional harvest of habitat.

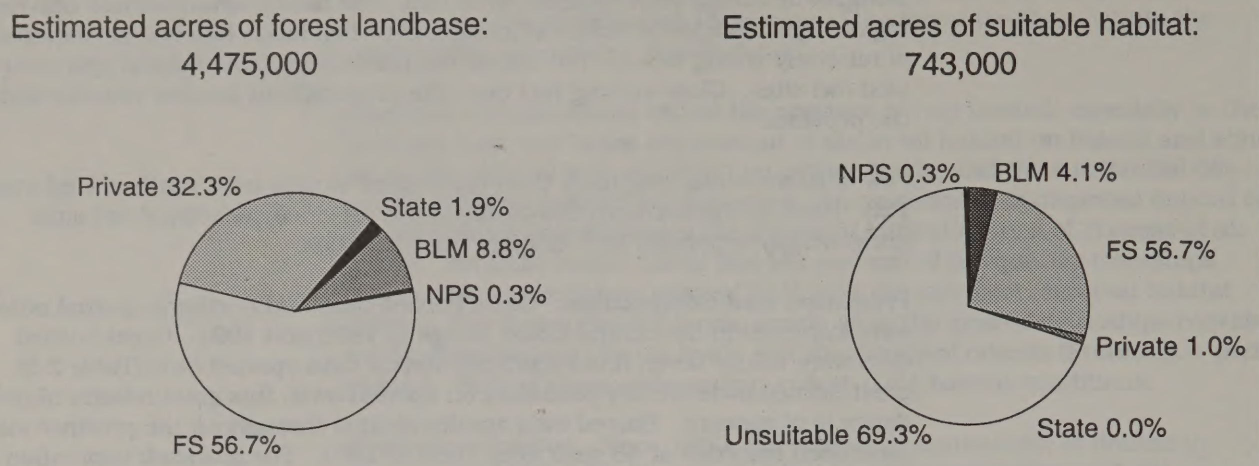
Historically, there was probably a significant connection between the Oregon Coast Range province and the western Washington lowlands province, with owls crossing the Columbia River. Timber harvest since 1920 likely has eliminated this connection. To increase the likelihood of owl recovery in these provinces, habitat would have to be developed along both sides of the Columbia River to reestablish the connection between these two provinces.

Vulnerability to Natural Disturbance. Extensive fires historically have removed large areas of habitat, although return intervals have been long, and annual risk is fairly low. Because current suitable habitat areas are limited and disconnected, disturbance events could remove key areas.

Western Oregon Cascades

This province lies west of the crest of the Cascade Mountains and extends the length of the state from the Columbia River to the California border. Habitat extends from the eastern edge of the Willamette Valley upslope to about 5,000 feet, and from the moist, true-fir forest in the north to the dry, mixed conifer-pine-oak woodlands in the south. Ownership in this province is 54 percent Forest Service, 34 percent private, 10 percent BLM, and 2 percent state (Figure 2.5a).

Low Populations. Owl populations within this province are moderately high, as is the amount of remaining habitat on federal lands. Areas with low owl numbers occur on 1) private lands, 2) checkerboard BLM lands at lower elevations, 3) checkerboard Forest Service lands in the Santiam Pass area, and 4) higher elevation forests near the Cascade Crest. There are approximately 925 known spotted owl pair sites in this province. Owl use of habitats above 5,000 feet elevation is very limited and few pairs successfully nest above 4,500 feet in this province.



BLM = U.S. Bureau of Land Management
FS = U.S. Forest Service
NPS = National Park Service
Sources: Mellen (pers. comm.), Neitro (pers. comm.), Johnson (pers. comm.), Bruce (pers. comm.), Starkey (pers. comm.), Greber et al. (1990).

Figure 2.5a. *Land base and suitable habitat, western Oregon Cascades.*

Declining Populations. Based on demographic data gathered from the H.J. Andrews study area from 1987 through 1991, populations in the central portion of the province are declining by about 7 percent annually (lambda = 0.928)(Appendix C). Additional demographic data come from the Medford study area in the southern part of the province. Most of the Medford study area lies within the Klamath province and the remainder is within the western Cascades province. Using data pooled from both provinces within the study area, the annual rate of population decline is 16 percent (lambda = 0.844, Appendix C).

Limited Habitat. Although the western Cascades province has a higher owl density than in any other Oregon province, suitable owl habitat is limited mainly to federal lands (Figure 2.5a). Much of the suitable habitat of federal lands has been fragmented significantly in the past 40 years. For example, within areas approximately equal to the median home ranges of 383 owl-pair sites on the Willamette National Forest, 49 percent of the sites contained less than 40 percent owl habitat, 33 percent contained from 41 to 60 percent habitat, and only 11 percent contained more than 60 percent habitat. No data were available for 7 percent of the pairs (Byford, pers. comm.).

Johnson (pers. comm.) assessed the amount of old-growth and mature forest within 70 plots (totaling 86,695 acres) located at random on Forest Service land within the central portion of the province. The mean amount of old-growth and mature forest within these plots was 53 percent in 1990.

Declining Habitat. Timber harvest from all ownerships for the period 1950 to 1990 indicates an estimated annual rate of habitat loss of 1.4 percent for this province (Figure 2.5b). The rate of habitat loss on federal lands is approximately 1.0 percent annually.

Ripple et al. (1991) assessed the changes in forest fragmentation patterns from 1972 to 1987 on approximately 65,000 acres of national forest land in the

central portion of the province. They reported an 8.7 percent decrease in the amount of natural forest (as a result of timber harvest) and a concomitant 18.0 percent decrease in the amount of interior habitat. The loss of interior habitat, at nearly double the rate of timber harvest, reflected the harvest of timber in a checkerboard manner during the study period.

In a different study, Ripple (pers. comm.) used satellite imagery to assess the changes in the amount of closed-canopy forest and closed-canopy interior forest from 1972 to 1987 on an 866,950-acre study area in the western Cascades province. During this period, the proportion of closed-canopy forest was reduced from 71 percent to 58 percent, along with a significant reduction in closed-canopy interior forest. In this study, closed-canopy forest was defined as stands 30 to 40 years of age or older with more than 60 percent canopy closure, and closed-canopy interior forest was the amount remaining after removal of a 330-foot edge zone.

Distribution of Habitat and Populations. The north-to-south distribution of spotted owls through the central portion of this province is adequate, with the exception of the Santiam Pass area where owl sites are separated by 6 to 10 miles. Owls are scattered on BLM lands along the western portion of the province and some owl sites are isolated by intervening private lands with limited habitat. Few owls are found above 4,500 feet and little suitable habitat exists above 5,000 feet.

The forested lands on the flanks of the western Cascades between the national forest boundaries and the Willamette Valley floor are predominantly privately

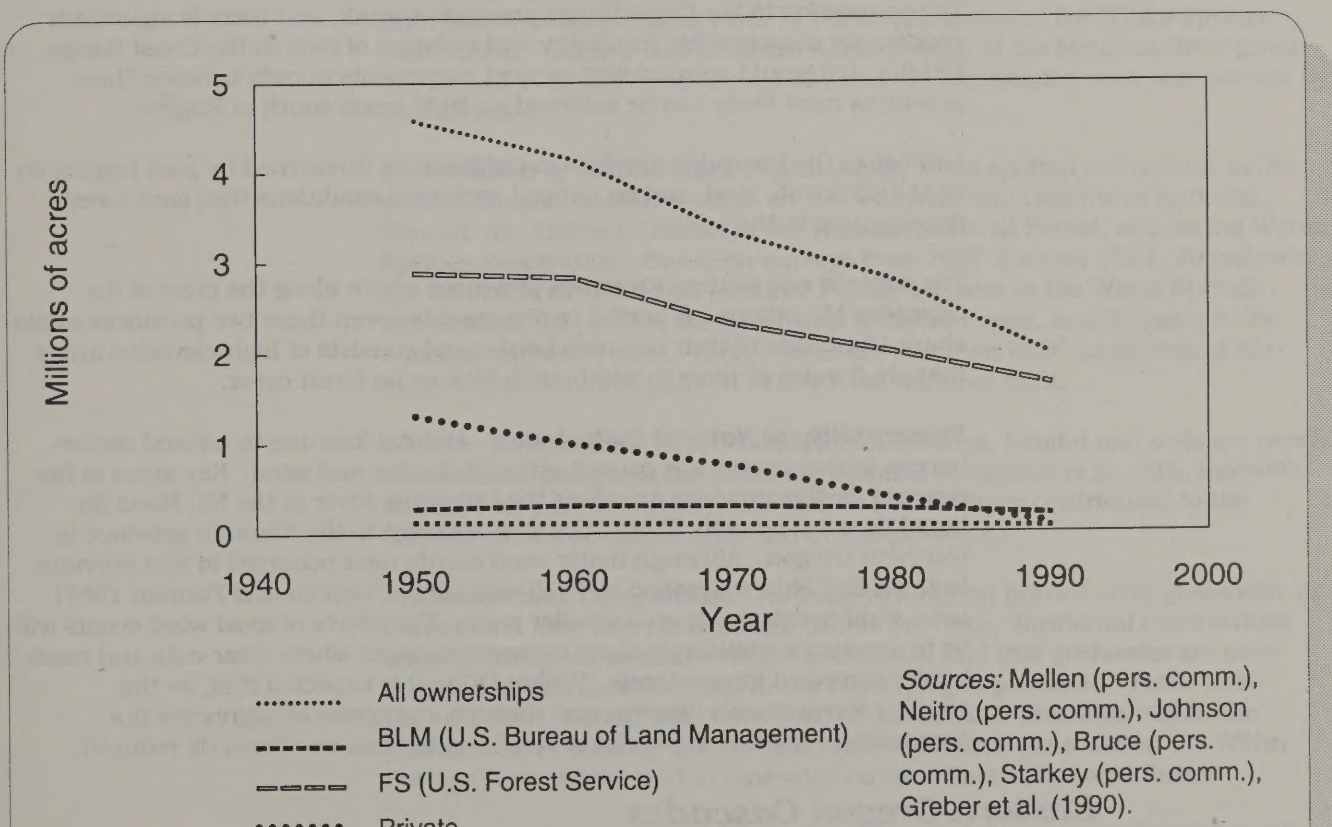


Figure 2.5b. *Trend in northern spotted owl habitat, western Oregon Cascades province.*

owned and contain little suitable habitat. Although owls are present in low numbers on some of these lands, it is unclear whether the owls are self-supporting or are a result of dispersing owls from nearby source populations.

Predation and Competition. Great horned owls and northern spotted owls were surveyed in the central portion of the province in 1989 and 1990, with great horned owls 60 percent as numerous as spotted owls (Johnson pers. comm., Table 2.5). Barred owls are distributed throughout the province and have been recorded at 156 locations from 1980 through 1991.

Goshawk densities are moderate within this province, and most goshawks are observed within habitats also used by northern spotted owls. Goshawk predation upon adult spotted owls has been observed (Desimone, pers. comm.).

Province Isolation. Prior to development of the Portland metropolitan area and the Willamette Valley, this province would have been connected to the Oregon Coast Range at least along the Willamette River between Wilsonville and the Columbia River. Another possible forested connection may have existed in the vicinity of Salem.

There is concern that the Columbia River Gorge, plus the effects of hydroelectric dams and other recent human activities along the river, have created a barrier to the movement of spotted owls between the Cascade provinces in Washington and Oregon. Spotted owl habitat in this area mainly occurs on the Mt. Hood National Forest in Oregon and Gifford Pinchot National Forest in Washington.

The connection to the Coast Range province is weak, and there is significant concern for demographic instability and isolation of owls in the Coast Range. Habitat that would support east-to-west movements of owls between these provinces most likely can be achieved on BLM lands south of Eugene.

Linkage to the Cascades province in California is threatened by past logging on BLM and private land, and by natural ecological conditions that limit forest development in the area.

The western and eastern Cascades provinces adjoin along the crest of the Cascades Mountains. A barrier to dispersal between these two provinces exists along 40 percent of their common border and consists of high-elevation areas that are 3 miles or more in width, with little or no forest cover.

Vulnerability to Natural Disturbance. Habitat loss due to natural disturbances in this province is caused primarily by fire and wind. Key areas of fire concern for this province are along the Columbia River in the Mt. Hood National Forest (Appendix F), and the area adjacent to the Klamath province in southern Oregon. Although major wind events have occurred in this province (e.g., on Bull Run watershed in 1973 and 1983, Franklin and Forman 1987) most wind events occur on a smaller scale. The effects of most wind events will be to accelerate windthrow along susceptible edges where clear-cuts and roads border protected forest stands. Within DCAs it is expected that, as the younger forest stands develop, and through a program of aggressive fire suppression, the loss of habitat to wind and fire can be effectively reduced.

Eastern Oregon Cascades

The eastern Oregon Cascades province is a narrow band of habitat extending north-to-south along the east side of the Cascade crest from the Columbia River to the California border. Habitat suitable for owls is found in the mixed conifer zone existing between the high-elevation subalpine and mountain-

hemlock forests and the lower elevation lodgepole/ponderosa pine areas. Most of the owls' range in this province is in federal and Indian ownership, although there is some state and private land at the southern end of the province.

Low Populations. The population of owls in this province is very low, primarily due to the inherently low potential for suitable habitat and due to the extent of timber harvest where habitat does exist. Only 163 pairs of owls were found in this province based on 1987 to 1991 surveys, with 89 percent of the owl sites on federal lands. The only area in the province where owl pairs occur in moderate numbers and distribution is within the Mt. Hood National Forest.

Federal lands in this province have been fairly well surveyed for owls, and the Warm Springs Reservation was surveyed in 1991. As a result of these surveys, an estimated 80 to 90 percent of the owl sites are known in the province. Demographic information for owls in this province is limited and no long-term studies have been undertaken.

Major threats to the owl population reflect viability concerns related to the generally poor distribution and low numbers of owl sites, and the inability to provide suitable habitat conditions over the long-term (due to changes in forest-tree species composition and large fires).

Limited Habitat. Because of natural limitations of the landscape it will be difficult to achieve habitat conditions where large clusters of owls (i.e., 20 or more pairs) can be sustained. The alternative is to provide for smaller clusters, relatively near one another, where current or potential habitat exists. Fairly contiguous (although fragmented) habitat conditions exist from the Columbia River south to the Metolius River at the southern end of the Warm Springs Reservation. Current and potential habitat south of the Metolius River generally occurs in blocks less than 4,000 acres in size, isolated from one another by 4 to 25 miles.

Distribution of Habitat and Populations. Most spotted owl habitat in the eastern Oregon Cascades exists on the Mt. Hood and Deschutes National Forests, the Klamath District of the Winema National Forest, and on the Warm Springs Reservation. Based on surveys from 1987 through 1991, 70 owl pairs are known in the Mt. Hood National Forest, 16 pairs in the Warm Springs Reservation, 30 pairs in the Deschutes National Forest, and 37 pairs in the Winema National Forest. Eleven pairs are found on BLM lands west of Klamath Falls, and three pairs in Crater Lake National Park.

With the exception of the Mt. Hood National Forest, habitat and owls are poorly distributed throughout the province. Natural conditions (e.g., soils, moisture conditions), past fire history, and timber harvest have contributed to the isolated nature of habitat and owls in this province.

Predation and Competition. No surveys for great horned owls, goshawks, or barred owls have been undertaken in this province. Incidental observations suggest that great horned owls are numerous, and that goshawks are more common in this province than in the other Oregon provinces. From 1980 through 1991, barred owls have been observed at 27 locations within the province; at 17 sites on the Mt. Hood National Forest, one site on the Warm Springs Reservation, and at nine sites on the Winema National Forest.

Province Isolation. Due to high-elevation subalpine and nonforested conditions along 40 percent of the Cascade crest, the eastern Oregon Cascades province is relatively isolated from the western Cascades province. These conditions pose a barrier for owls in the vicinity of the Three Sisters Mountains, and from Willamette Pass south to about 25 miles south of the southern boundary of Crater Lake National Park.

Vulnerability to Natural Disturbances. The potential for large-scale loss of owl habitat to fire is higher here than it is for any other Oregon province. There is a low probability that any conservation area created in the eastern Cascades of Oregon will avoid a stand-replacing fire over a significant portion of its landscape during the next century (Appendix F).

Klamath (Oregon Portion)

The Klamath province covers large portions of southwestern Oregon and northern California. The Oregon portion lies south of the Coquille River and Roseburg, and west of Medford. Land ownership in the Oregon portion is 35 percent Forest Service, 30 percent BLM, 33 percent private, and 3 percent state (Figure 2.6a). Forest Service ownership includes the Siskiyou and parts of the Rogue and Klamath National Forests. BLM ownership includes much of the Medford District with lesser amounts of the Roseburg and Coos Bay Districts. The Oregon portion of the province is characterized by generally mountainous terrain (e.g., the Siskiyou and Klamath Mountains), a high diversity of forest tree species, often occurring in mixed stands, and large areas of serpentine soils, which generally are incapable of supporting forest conditions. Unforested talus slopes are common. Threats to the owl population include continued loss and fragmentation of habitat from timber harvest, a major threat of habitat loss from fires (see Appendix F), and a declining population.

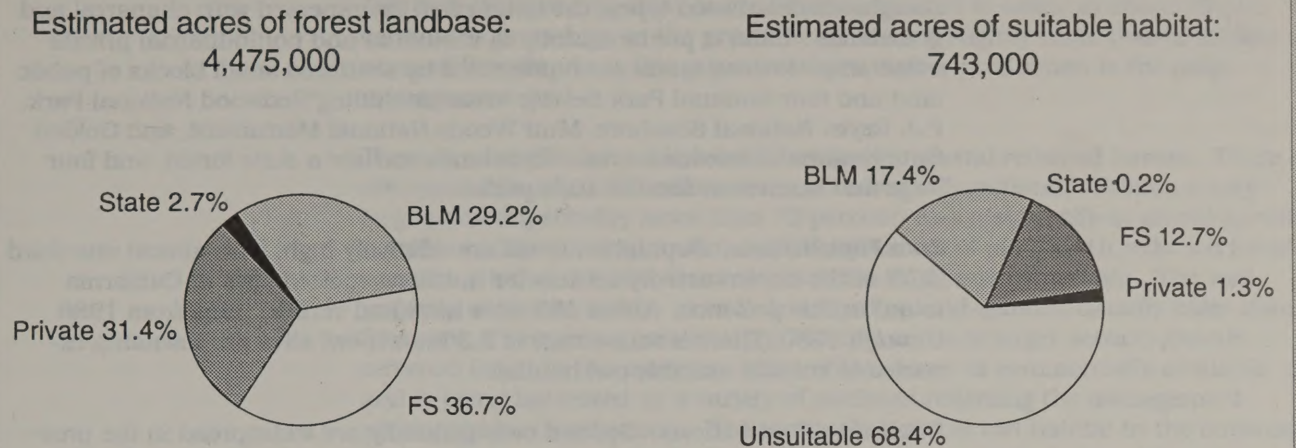
Low Populations. Numbers and density of spotted owls are moderate in this province, and the population generally is well distributed. Approximately 390 pairs have been found in the province from 1987 through 1991. However, demographic data indicate that the owl population is in significant decline. Poor habitat conditions (due largely to serpentine soils and high elevation) and low owl numbers occur within the Kalmiopsis Wilderness Area. Unlike the California portion of the province, few owl sites are known on private lands.

Declining Populations. Based on demographic data gathered from 1985 through 1991 in the Medford study area (Appendix A), owls in this area are experiencing the highest annual rate of decline (16 percent) in Oregon. The nesting success of owl pairs varies annually within all portions of the owl's range, but has been particularly low for this area (and for the Oregon Coast Range as well). In only 3 of the last 7 years has the percent of pairs producing young exceeded 50 percent (of the pairs present), with the highest being 60 percent in 1986 (the lowest was 14 percent in 1987).

Limited Habitat. Approximately 38 percent of the 3,102,000 acres of forested land in this province contains habitat suitable for owls (Figure 2.6a). This habitat is primarily on federal lands and is extensively fragmented, due to timber harvest patterns on the checkerboard and mixed land ownerships, as well as natural vegetation patterns.

Declining Habitat. The overall estimated rate of habitat decline for all ownerships within the province has been 1.3 percent per year for the period of 1950 through 1990. The rate of decline has accelerated in the last decade to approximately 3 percent annually, primarily reflecting a continued high level of harvest on private land and an increased level of harvest on federal lands (Figure 2.6b).

Distribution of Habitat and Populations. In general, owls and owl habitat are reasonably well distributed within the province. Low owl numbers and/or poor habitat conditions exist in the Kalmiopsis Wilderness Area, on private lands, and within the areas of checkerboard BLM/private lands.



BLM = U.S. Bureau of Land Management
FS = U.S. Forest Service
Sources: Mellen (pers. comm.), Neitro (pers. comm.), Johnson (pers. comm.), Bruce (pers. comm.), Starkey (pers. comm.), Greber et al. (1990).

Figure 2.6a. *Land base and suitable habitat, Oregon Klamath province*

Predation and Competition. There have been no surveys for great horned owls or goshawks, and their impacts on northern spotted owls are poorly understood in this portion of the Klamath province. From 1980 through 1991, 22 barred owl locations were recorded in this province.

Province Isolation. Due to the fragmented condition of the habitat in the Roseburg and Medford areas, connectivity to the Coast Range and the western Cascades provinces is weak. An assessment of dispersal habitat, as described by Thomas et al. (1990), found that on BLM lands, 140 of 284 (49 percent) of quarter-townships containing one section or more of BLM lands did not contain habitat adequate for dispersal. Of Forest Service lands within the Siskiyou National Forest, 8 of 125 quarter-townships did not contain habitat adequate for dispersal (Webb, pers. comm.). Of particular concern are BLM/private checkerboard lands that are key linkage areas between the Klamath and adjacent provinces.

Vulnerability to Natural Disturbances. The potential for large-scale loss of habitat is high because of the regular occurrence of fire (Appendix F). Due to steep topography and changes in vegetation, fires in this province burn with varying intensities, and create a complex mosaic of burned, partially burned, and unburned areas. Although fires are often large (93,000 acres in the 1987 Silver fire), the total amount of owl habitat actually lost in a fire usually is not great.

6. Threats by Province within California

California Coast

The California Coast province extends south from the Oregon border to San Francisco Bay and from the ocean inland to the western border of national forest lands. The coastal portion of the province encompasses the majority of the redwood forest habitat type. Inland forests are Douglas-fir and mixed

Douglas-fir/hardwood types, the latter often interspersed with chaparral and grasslands. Land is predominantly in industrial and nonindustrial private ownership. Federal lands are represented by scattered small blocks of public land and four National Park Service areas, including Redwood National Park, P.J. Reyes National Seashore, Muir Woods National Monument, and Golden Gate National Recreation Area. State lands include a state forest, and four large and numerous smaller state parks.

Low Populations. Population levels are relatively high, with almost one-third (370) of the known activity centers for northern spotted owls in California found in this province. About 155 sites have had verified pairs from 1986 through 1990. There is an average of 2.3 known owl sites per township expected to contain suitable owl habitat.

Declining Populations. Spotted owls generally are widespread in the province, having been found in 56 percent of the townships in the province, or in 71 percent of the townships where suitable habitat exists and thus where they would be expected to occur. One known or no owl sites have been found in 50 percent of the townships where the owl would be expected to occur. More than nine sites each are known from three townships, indicating that some habitat conditions can support high densities. One township on heavily harvested, commercial redwood forestland supports at least 18 sites.

Demographic information indicates that owls in this area are occupying sites and reproducing at rates similar to owls in other areas. Survival information is limited so estimates of population stability are not possible.

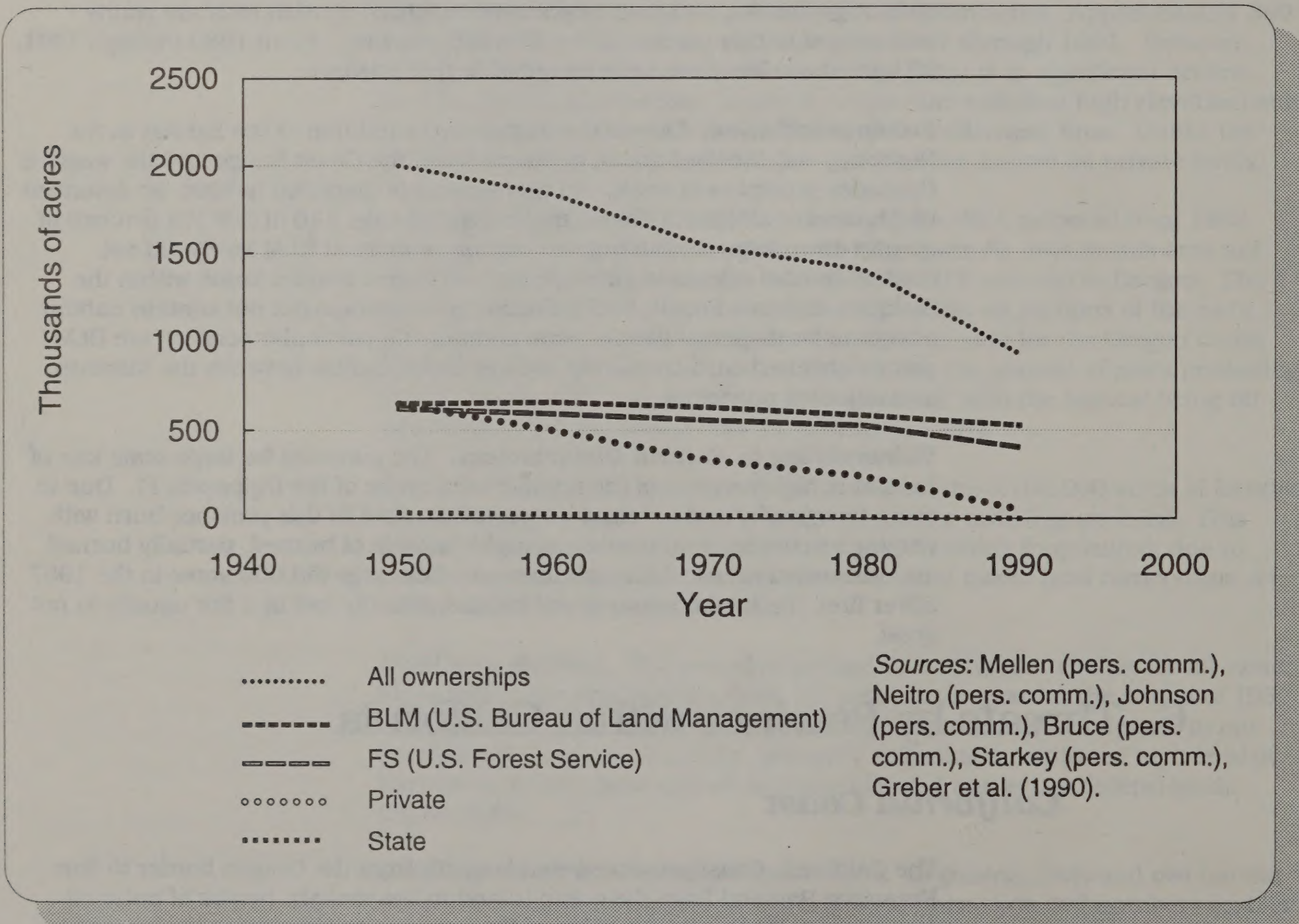


Figure 2.6b. *Trend in northern spotted owl habitat, Klamath province (Oregon portion).*

Limited Habitat. Spotted owl habitat is expected to occur in about 79 percent of the townships in the province. There are slightly more than 2 million acres of forestlands in this province where timber production is the main management goal.

There is a long history of habitat alteration in coastal redwood forests. There are approximately 1.95 million acres of redwood forestland, of which a very large portion (probably more than 75 percent) was historically in an old-growth condition. There are approximately 85,000 acres of old-growth redwood forest remaining today, 21,000 acres of which are in private ownership. The vast majority of known owls is in well-developed second-growth, usually older than 50 years. There are approximately 740,000 acres of larger second-growth redwood forest in the province. Most of this forest is commercially available and is being harvested by a variety of methods reflecting the management philosophies of landowners. The currently suitable owl habitat in the redwood timber type appears to be high quality, and most neighboring pairs are not widely separated.

Douglas-fir and Douglas-fir/hardwood forests predominate in the timbered land inland from the redwood belt. This area occupies roughly a quarter of the province with the remaining portion being brush and oak/brush lands. These generally unsuitable lands for owls are interspersed with, and in some areas naturally fragment, the more suitable Douglas-fir and Douglas-fir/hardwood forests. There are no commercially available old-growth Douglas-fir or Douglas-fir/hardwood forests in the province, but harvest occurs in the second-growth Douglas-fir types.

Declining Habitat. Redwoods are limited geographically to the coastal portion of this province. The wood is in relatively high demand, and available old-growth is rare. Harvest on private lands in the north coast accelerated during the 1980s. From 1986 through 1989, the average annual acreage cut in this area was 102,029 acres. Approximately 83,000 of those acres, or about 4 percent of the timber producing lands, were treated annually with stand-replacement harvests. Protected second-growth habitat within Redwood National Park will provide additional habitat as these stands mature.

Distribution of Habitat and Populations. Owls and owl habitat generally are abundant and widespread across the northern and western portions of the province where redwood and coastal Douglas-fir habitats predominate. Owl densities average 3.6 known owl sites per township where suitable owl habitat is expected to occur.

In some areas of the province, owl habitat is distributed naturally in an irregular pattern. A north-to-south band from southeastern Humboldt County to central Mendocino County contains a natural mix of Douglas-fir forest in canyons, hardwood forest on slopes, and grasslands on ridges. This area is relatively unsurveyed, but the distribution of owls and their habitat is not continuous. Similar conditions, without the Douglas-fir forests, continue south through Lake County. One-third of the townships in this area is not expected to contain suitable owl habitat. On average, one known owl site occurs in those townships that are expected to contain suitable habitat.

Owl populations in Marin County, and Napa and Sonoma Counties (21 and 27 sites respectively) are isolated. Naturally occurring grasslands and hardwood/brush areas separate these owl populations from the continuous range of the subspecies that occurs to the north and northwest. The Napa and Sonoma County owls are 16 to 20 miles from the main body of the population in western Sonoma County and 32 miles from owls in the southern part of the Klamath province in Lake County. The Marin County population is at least 17

miles from the contiguous population of owls in the province to the north and 27 to 31 miles from the other isolated population in Napa and Sonoma Counties to the east.

Owl habitat in the province is found on a greater variety of ownerships than in any other province of the state. Private industrial land ownerships comprise the largest single group. The multiplicity of ownerships in Marin, Napa, and Sonoma Counties, along with early logging history, agricultural, and residential land developments have resulted in extensive habitat fragmentation. Coordination and cooperation will be necessary in achieving recovery in this province.

Province Isolation. Owl habitat is contiguous along the northern two-thirds of the 220-mile boundary between the California Coast and California Klamath provinces. In the southern one-third, suitable habitat in both provinces is naturally fragmented, and owl sites are at lower densities. The southern end of the province is isolated from other provinces, although the range of the California spotted owl extends to within 110 miles to the south (across San Francisco) and 90 miles to the east (across the Sacramento Valley).

Predation and Competition. Great horned owls, red-tailed hawks, and ravens occur naturally throughout the province. Natural grasslands are interspersed throughout the province and their occurrence indicates a history of contact between grassland and forest species. However, current logging is opening second-growth stands, and when forests are limited this harvest decreases the area available as refuge from avian predators.

Barred owls were first identified in the province in 1981. Seven of the nine known barred owl sites have been found in the last 3 years. Currently, competition from barred owls in the province appears to be low, but barred owls occupy at least one site previously occupied by northern spotted owls, and a hybrid is known to have paired with a northern spotted owl (Gould pers. comm.).

Vulnerability to Natural Disturbance. Fire probably is the major, short-term disturbance event that would affect forests in the province (Appendix F). Much of the coastal area supports moist redwood and Douglas-fir forests that do burn. However, fires are generally smaller and less frequent than those in provinces farther inland. In the mixed Douglas-fir/hardwood/grassland zone on the eastern side of the province, fire is a considerably more frequent event. Wind damage, and insect and drought problems also appear to be relatively minor in the province.

Klamath (California Portion)

The California Klamath province is located between the California Coast province and the California Cascades province. It is a continuation of the Oregon Klamath province south to the Clear Lake Basin in the Inner Coast Range. The area is mountainous and covered primarily with Douglas-fir forests. Mixed Douglas-fir forests are common at lower elevations with Douglas-fir/true fir forest at higher elevations. The province primarily consists of four national forests and includes four major wilderness areas. There are a few parcels of other public lands and some private forestlands. The private and public lands mostly occur near the eastern edge of the province.

Low Populations. Owl populations are moderate in this province, which contains 750 sites. There have been about 455 pairs verified from 1986 through 1990. Suitable habitat contains an average density of 3.7 known owl sites per township.

Declining Populations. Spotted owls generally are widespread in the province, having been found in 85 percent of the townships in the province and in 95 percent of the townships where suitable owl habitat would be expected to exist. One or no owl sites have been found in 23 percent of the townships where the owl is expected to occur. More than nine sites each have been found in seven townships, and one township has 20 known sites. Populations in the Willow Creek study area have been decreasing by nearly 9 percent annually during the last several years (Appendix C). In some areas known sites have disappeared due to habitat modifications.

Limited Habitat. There are an estimated 1,070,000 acres of suitable owl habitat in Forest Service lands in northern California, of which 80 percent is estimated to be in the Klamath province. Additional habitat is found on private lands which generally occur along the eastern edge of the province.

Habitat generally is not highly fragmented and individual pairs normally are not isolated or becoming isolated in the western and central parts of the province. Along the eastern edge, there are areas of poorer soils, intrusions of higher-elevation areas and drier conditions, all of which result in lower amounts of suitable owl habitat. Natural fragmentation and the isolation of individual pairs (such that sites are more than 6 miles apart) occur at the southern end of the species' range in this province. Forest is limited or absent in this area due to lower and drier conditions.

Declining Habitat. There has been significant loss of habitat to clear-cutting on national forest lands, most of which has occurred since the mid-1940s. A reduction of 40 percent (212,000 acres to 126,200 acres) in the area of mature and old-growth, closed-canopy forest has occurred on the Six Rivers National Forest. This occurred with an average annual harvest (1960 to 1984) of 158.6 million board feet. Other national forests probably are undergoing a decrease in available habitat with average annual cuts of 80.2 million board feet (prior to 1984) on the Mendocino National Forest and 248.0 million board feet (1974 to 84) on the Shasta-Trinity National Forest.

Much of the lower elevation, mixed conifer forest on private lands along the northeast edge of this province was cut heavily earlier in the century. The resultant second-growth now is being cut, primarily using uneven-age management techniques. This has resulted in less absolute loss of suitable habitat than clear-cutting would have, but the level of successive partial cuts that might cause degradation of owl habitat is not known. From 1986 through 1990, the average area harvested on private lands in Glenn, Shasta, Siskiyou, Tehama, and Trinity Counties (some areas also in the Cascades province) was 103,000 acres per year. An average of 41,000 acres was in stand-replacement harvest prescriptions.

Distribution of Habitat and Populations. Owls and owl habitat are present within 92 percent of the townships in the province, and are found across the full range of ecological conditions that provide suitable owl habitat within the province. Owls and owl habitat generally are well distributed throughout the western and most of the central portion of the province.

The eastern and southern parts of the province are drier, the forest is more fragmented, and owl densities are lower than in the western and central part of the province. The northeastern section also contains a large, lower-elevation valley with unsuitable owl habitat. A third of the townships in the eastern section are not expected to have owls, or have owls at low densities. Spotted owls have been found in 94 percent of the townships that would be expected to have owls because of the presence of suitable habitat.

In comparison, the southern part of the province is typified by dry, brush-covered, south-facing slopes and forested, north-facing slopes. Owls occur in 96 percent of the townships in the southern part. Only 4 percent of the townships have more than four owl sites each, while 24 percent and 42 percent of the townships in the eastern and north/central parts of the province, respectively, have more than four known sites per township.

Province Isolation. This province is located between the other two California provinces and is continuous with the Oregon Klamath province. Owls and habitat occur along the borders with the three other provinces except where areas of natural habitat fragmentation occur along the southwest and north-east boundaries. The Klamath province is contiguous with the California Coast province for the first 115 miles south from the Oregon border. It is probably contiguous with the same province for another 105 miles but the habitat in the adjoining California Coast province supports mostly dispersal habitat and little breeding/roosting habitat.

The Klamath province is contiguous with the California Cascades for about 110 miles. However, suitable owl habitat only occurs along the mutual border between the two provinces for the 55 miles south of Shasta Valley. Habitat here is not contiguous and is found as pockets of suitable habitat among areas of higher elevations, unsuitable soils, or past timber harvest. South of Redding, the remainder of the eastern border of this province directly abuts California's Central Valley, which is not suitable habitat. Suitable habitat in the range of the California spotted owl is 35 to 80 miles to the east in the Sierra Nevada.

Predation and Competition. Great horned owls occur naturally throughout the province. Predation on spotted owls by great horned owls has been noted in field studies in the province. Additional studies will be required to determine whether great horned owl numbers are increasing.

Barred owls have been identified in the Klamath province during the last 8 years. This number has grown dramatically in the last 3 years from 4 to 15 known sites. Pairs of barred owls were found at one-third of these sites in the last 2 years. The potential for competition may be increasing rapidly, but the effects on local spotted owls are not known.

Vulnerability to Natural Disturbance. Fire is the major disturbance event likely in the Klamath province. This area has a history of many natural fires. However, fire suppression during the last 70 to 100 years has resulted in increased accumulation of fuels and has made large and hot fires more likely than was true historically. This has led to a recent history of large fires (e.g., Hog fire on Klamath National Forest; 1987 fires on Klamath, Shasta-Trinity and Mendocino National Forests).

Wind damage is a relatively small problem compared to other parts of the Pacific coast. Drought and drought-caused insect and disease problems are of concern, especially in some of the drier areas.

California Cascades

The California Cascades province is located in the north central portion of the state, between the Oregon Cascades provinces, the Klamath province, and the range of the California spotted owl at the north end of the Sierra Nevada. Suitable owl habitat generally is fragmented on a broad scale by the Shasta Valley, Mt. Shasta, and other high-elevation areas of unsuitable soils, and areas of marginal, low-elevation habitats. Suitable forest habitat is mostly on national forests, although there are significant blocks and checkerboard areas where forests occur on mostly industrial private lands.

Low Populations. Population levels are low in this province. There are only 71 known sites, or only about 6 percent of the known sites in California. Pairs have been verified at about 35 sites from 1986 through 1990. The density of sites found since 1970 is only 1.0 per township.

Declining Populations. Owls and owl habitat are present across a range of ecological conditions within the province, but habitat is fragmented. Owls are known from only 40 percent of the townships in the province and from 51 percent of the townships where possibly suitable habitat exists. Even though the area is fairly well surveyed, 48 percent of the townships with owls have only one known owl site, and only 5 percent have more than four owl sites each. Even where owls occur, population densities are low in the province.

Demographic information for owls in the study area is scarce. There is no demographic information from field studies. The only available information is limited to survey and inventory work with anecdotal observations of reproduction, Forest Service monitoring sites, and private lands surveys which have been conducted only in the last 2 years.

Limited Habitat. The California Cascades province is small, containing only about 110 townships. Twenty-three of these townships probably do not contain suitable owl habitat and another 43 contain only marginal habitat. Habitat is mainly found on parts of the Klamath and Shasta-Trinity National Forests and interspersed private lands. There are about 500,000 acres of land suitable for timber harvest on the Shasta portion of the Shasta-Trinity National Forest. About 220,000 of these acres are in stands with crown diameters greater than 13 feet and canopy closure greater than 40 percent. However, much of this area does not meet the Interagency Scientific Committee's (ISC) "50-11-40" standard for dispersal habitat (Thomas et al. 1990).

Declining Habitat. Timber harvesting often extends over large areas, but commonly does not involve clear-cutting. Habitat loss in this area is difficult to estimate because of the patchy distribution of habitat chosen by the owls, perhaps the result of previous tree cutting and/or thinning and the possibly low historical levels of suitable habitat due to fire history.

Distribution of Habitat and Populations. Habitat is fragmented throughout the province. Landscape-scale fragmentation is demonstrated by the division of the 44 townships where owls are found in six separate clusters. Suitable habitat is fragmented on a local level and individual owl sites are often widely separated from nearest neighbors. This fragmentation and the isolation of individual sites may be natural in part and partially the result of timber harvest. There is only one area where the ISC found a block of contiguous habitat sufficiently large to form a habitat conservation area that would support 16 sites.

The eight sites north of Goosenest Mountain in the Klamath National Forest and private lands are the only isolated population in the province. Natural barriers (Shasta Valley, Klamath River Canyon, and a high-elevation pass) separate this area from the remainder of the province and from other adjacent provinces.

Province Isolation. The California Cascades province is bordered on the west and north by the California and Oregon Klamath provinces, the western Oregon Cascades and the eastern Oregon Cascades provinces. It abuts the range of the California spotted owl to the southeast. Although the province is bounded by others on three sides, it is somewhat isolated from those provinces. The Shasta Valley separates the northern California Klamath province from the Goosenest section of the California Cascades by 20 miles. The

Sacramento River Canyon now provides a 10- to 13-mile division between known owl sites in the California Klamath and Cascades provinces. A narrow band (about 20 miles wide) of low-density owl habitat provides an obstacle to owl movement between the California Cascades and the northern Sierra Nevada. While there are forests in some of these gaps, habitat quality and owl densities in these areas are low. These conditions may be sufficient to ensure genetic connection, but probably limit the amount of demographic support that could be provided by adjacent provinces.

Predation and Competition. Great horned owls naturally occur throughout the province because of the open forest condition and the history (more than 50 years) of large-scale habitat modifications in the province. Fire suppression probably has resulted in the exclusion of great horned owls from some forest habitats that are now denser than they were historically.

Barred owls were first identified at two sites in the province in 1991. The current competition from barred owls is probably low, but is potentially detrimental, especially for this sparse and high-risk spotted owl population.

Vulnerability to Natural Disturbance. Fire is the major natural disturbance likely in the California Cascades province. Fire may not be as great a problem as in the Klamath province, because of the presence of areas of naturally poor soils and sparser vegetation. However, fire probably affected the composition and structure of the historic forest. Fire suppression during the last 70 to 100 years probably has increased vulnerability of the forest to wildfires. Wind damage is a minor problem, but drought and insect/disease problems are of concern.

II. C. Current Management

Habitat of the northern spotted owl is managed by many individuals, corporations, federal and nonfederal agencies, and Indian tribes. The large number of entities involved and the diversity of statutory and regulatory authorities under which land is managed pose a challenge and provide opportunities for coordinating landscape-level conservation measures for the species. The following sections explain federal, state, and Indian land management authorities throughout the range of the northern spotted owl. The sections are organized to accommodate the specific roles played by the groups that will participate in recovery. In each case, the intention is to show the means available to participants carrying out the recovery plan.

1. Forest Service

Management Background

Prior to the early 1970s, little was known about the northern spotted owl in national forests in Washington, Oregon, and California except that it resided in a variety of forest types. Early research in Oregon and California indicated an association with mature and old-growth forests.

In 1973, an interagency committee was organized, consisting of biologists from the Forest Service, BLM, FWS, Oregon Department of Fish and Wildlife, and Oregon State University. The committee, known as the Oregon Endangered Species Task Force, recommended that 300 acres of old-growth forest be retained around every known spotted owl nest site.

During the next 3 years, research provided information about spotted owl habitat needs (Gould 1974; Forsman 1976). In November 1976, the regional forester for the Pacific Northwest Region directed that nesting sites of spotted owls be protected on national forests in Oregon, as prescribed by the task force, until biological unit management plans were developed.

In 1976, the Oregon Endangered Species Task Force recommended a long-range goal to maintain 400 pairs of spotted owls on public lands in Oregon. The task force spent 1977 developing objectives and management prescriptions to meet that goal. For that 1-year period, the task force recommended that involved agencies protect locations around northern spotted owl nests and areas where spotted owls had been sighted.

On November 3, 1977, the Oregon Endangered Species Task Force released its Interagency Spotted Owl Management Plan. In the plan, national forests in Oregon were requested to support at least 290 pairs of spotted owls, the BLM was asked to support 90 pairs of spotted owls, and 20 pairs were identified for lands in other ownerships. Each pair of spotted owls was to be provided with a minimum of 1,200 contiguous acres of habitat consisting of a core area of at least 300 acres of old-growth conifer forest (to the extent it was available) and an additional 900 acres, of which at least 50 percent was to be in stands more than 30 years old. Additional criteria were given for the distribution of habitat and proximity among pairs of spotted owls.

On January 11, 1980, there was an appeal of the decision not to prepare an environmental assessment or an environmental impact statement prior to adoption of the Oregon Endangered Species Task Force's Spotted Owl Management Plan. The Chief, U.S. Forest Service, Washington, D.C., upheld the decision by the regional forester for the Pacific Northwest Region. However, the Chief directed that the Regional Guide for the Pacific Northwest Region, and accompanying environmental impact statement include (1) a biological analysis to determine the number and distribution of spotted owls that would constitute a viable population, (2) regional management and monitoring standards, and (3) an evaluation of needed research. The Forest Service also directed that until the regional plan was approved, 290 pairs of spotted owls should be protected on national forests in Oregon using the guidelines in the Interagency Spotted Owl Management Plan. Where necessary, adjustments were to be made to timber sales offered after October 1, 1980.

In October 1980, national forests in Washington were directed to protect, in accordance with the Interagency Spotted Owl Management Plan, the habitat of all confirmed spotted owl pairs, In April 1981, tentative allocations of spotted owls were assigned for the Gifford Pinchot, Mt. Baker-Snoqualmie, Olympic, and Wenatchee National Forests. These allocations totaled 112 pairs of spotted owls.

Also in 1980, the Spotted Owl Subcommittee, which replaced the task force, revised its Spotted Owl Management Guidelines in light of additional research and information. Results of radio-telemetry studies of spotted owls (Forsman 1980) became available in December 1980. These studies indicated that the amount of suitable habitat that existed within 14 home ranges studied was much greater than 300 acres. The Spotted Owl Subcommittee also worked with other consultants during 1980. Dr. Michael Soulé recommended protection of a population of 500 or more pairs for genetic reasons.

Based on the report from Forsman (1980) and consultation with Soulé, the Oregon-Washington Interagency Wildlife Committee revised the Interagency Spotted Owl Management Plan in February 1981. The revision called for 1,000 acres of old-growth habitat to be maintained for each spotted owl pair, with 300 acres around the nest site, if known, and an additional 700 acres within 1.5 miles of the nest site.

In May 1981, the Forest Service issued the Draft Pacific Northwest Regional Plan. The plan contained direction on the number and distribution of spotted owl pairs to be evaluated in forest planning. It also included in the appendix the February 1981 revision of the Oregon Interagency Spotted Owl Management Plan.

In 1982, the Forest Service, in cooperation with the BLM, initiated an Old-Growth Wildlife Research and Development Program in the Forest Service's Pacific Northwest Research Station.

During 1984, more information about spotted owls was published by Forsman et al. (1984). In May of 1984, the Regional Guide for the Pacific Northwest Region and accompanying final environmental impact statement were published. These documents replaced the draft environmental impact statement for the regional plan. The regional guide included standards and guidelines for forest-level planning of spotted owl habitat management, and directed national forests to analyze the effects of protecting at least 375 pairs of spotted owls in Oregon and Washington national forests.

Interim direction in the regional guide specified that until forest plans were approved, national forests were to manage for the tentative regional total of 402 pairs, with each pair being allocated 300 acres of old-growth habitat.

In April 1984, national forests in Oregon and Washington were directed to locate habitat areas to maintain a well-distributed population of spotted owls. Establishment of habitat areas subsequently was considered necessary and sufficient to meet the management requirement for population viability.

On October 22, 1984, the National Wildlife Federation, Oregon Wildlife Federation, Lane County Audubon Society, and Oregon Natural Resources Council filed an administrative appeal to the standards and guidelines for management of northern spotted owl habitat contained in the regional guide. The regional guide was remanded to the Forest Service with direction to prepare a supplemental environmental impact statement.

In California, several national forests had not yet begun by 1984 to implement the regional standards and guidelines because of delays in preparing individual forest management plans. The California Department of Fish and Game and the Forest Service agreed that regional standards and guidelines should be implemented before existing owl management options were lost. As a result, a network of spotted owl habitat areas was established on all western Sierra Nevada and northwestern California national forests.

In January 1987, the Forest Service's Pacific Northwest and Pacific Southwest Regions and Research Stations initiated the Northern Spotted Owl Research, Development, and Application Program. This program was designed to accelerate and coordinate all Forest Service activities concerned with owl habitat and population inventory, monitoring, and research. Results of the program have been used by the Forest Service to amend and revise direction for owl habitat management.

In December 1988, the Chief of the Forest Service approved an amendment to the regional guide for the national forests in Oregon and Washington. This amendment adopted standards and guidelines for management of spotted owl habitat in Washington and Oregon, initiated an accelerated research project on the owl's habitat requirements, and committed the Forest Service to revisit the decision in 5 years or sooner should new information become available.

On February 8, 1989, a complaint was filed in the federal District Court in Seattle by the Seattle Audubon Society and other environmental organizations, alleging that the Forest Service's adoption of the amendment to the Regional Guide for the Pacific Northwest violated the National Forest Management Act (NFMA), the National Environmental Policy Act (NEPA), and the Migratory Bird Treaty Act (MBTA). The plaintiffs requested a preliminary injunction on all timber sales containing 40 or more acres of spotted owl habitat on the 13 national forests with owls in Washington and Oregon. In March 1989, the court enjoined 163 timber sales pending further hearings.

Section 318 of the 1990 Interior and Related Agencies Appropriation Act addressed the issue of the spotted owl; the Seattle Audubon Society lawsuit in particular. The act provided additional protection for old-growth forests and existing designated areas managed for spotted owls.

The 1990 appropriation act directed the Chief of the Forest Service to revise his December 1988 decision. Further, the act directed him to consider the conservation strategy being developed by the ISC in the revised decision. "A Conser-

vation Strategy for the Northern Spotted Owl, Report of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl," was released in April 1990 (ISC).

On September 28, 1990, the Department of Agriculture gave notice that the Forest Service was vacating the December 1988 Record of Decision regarding spotted owl management and that it would manage, ". . . not inconsistent with the ISC Report."

On October 22, 1990, the Seattle Audubon Society filed an amended complaint with the federal District Court in Seattle alleging that the September 3, 1990, notice vacating the 1988 Record of Decision and the spotted owl habitat area system were illegal. Twelve timber sales were challenged under NFMA, NEPA, and MBTA aspects of the case, and were enjoined in December 1990.

The court ruled on March 7, 1991, that listing of a species under the Endangered Species Act did not relieve the Forest Service of its duty to ensure a viable population of the species. The court also held that the October 3, 1990, notice was adopted in violation of NFMA regulations. Eventually, the Forest Service was enjoined from auctioning or awarding any timber sales in suitable owl habitat while the agency prepared an environmental impact statement and otherwise complied with the court's orders.

The Forest Service filed a notice of intent to issue an environmental impact statement on May 8, 1991, and invited public comment for 3 months. The draft environmental impact statement was issued in September 1991. A final environmental impact statement was completed and the record of decision was signed on March 3, 1992.

Applicable Law

National Forest Management Act. This is the principal law governing management of the national forest system. It requires that national forests develop land and resource management plans. These plans must be updated every 10 to 15 years. The act requires that the plans include but not be limited to the following:

1. An analysis of present and anticipated uses, demand for, and supply of the renewable resources, with consideration of the international resource situation, and an emphasis on pertinent supply and demand and price relationship trends.

2. An inventory, based on information developed by the Forest Service and other federal agencies, of present and potential renewable resources, and an evaluation of opportunities for improving their yield of tangible and intangible goods and services, together with estimates of investment costs and direct and indirect returns to the federal government.

3. A description of Forest Service programs and responsibilities in research, cooperative programs and management of the national forest system, their interrelationships, and the relationship of these programs and responsibilities to public and private activities.

4. A discussion of important policy considerations, laws, regulations, and other factors expected to influence and affect significantly the use, ownership, and management of forest, range, and other associated lands.

Table 2.6. Estimated acres of spotted owl habitat on BLM lands in Oregon, California, and Washington.

State and District	Nesting Habitat	Roosting and Foraging	Total Habitat (Acres)	Total Forest (Acres)
Oregon				
Salem	53,300	120,335	173,665	372,799
Eugene	64,381	55,983	20,364	302,125
Roseburg	117,456	94,724	212,180	395,327
Coos Bay	99,912	23,284	123,196	308,888
Medford	168,715	233,352	402,067	835,189
California				
Ukiah	25,000	[a]	25,000	184,640
Washington				
Spokane[b]	600	1,500	2,100	3,000

[a]Not yet surveyed
[b]Hedges (pers. comm.)

2. Bureau of Land Management

Within the geographic range of the northern spotted owl, the Bureau of Land Management (BLM) administers 2.4 million acres in Oregon, Washington, and California. These lands include public as well as railroad grant lands that reverted to federal ownership pursuant to the Oregon and California Sustained Yield Act (O&C Act). The reverted grant lands comprise alternate sections in a checkerboard arrangement in the Medford, Eugene, Coos Bay, Salem, and Roseburg districts in western Oregon. The BLM Oregon office manages the greatest amount of owl habitat, followed by the California and Washington offices, respectively (Table 2.6).

Management Background

The first BLM northern spotted owl habitat management initiative consisted of 79 areas identified for management as spotted owl habitat in an agreement with the State of Oregon as components of the individual district office timber management plans completed in 1983. Each agreement site comprised 300 acres of contiguous old-growth or the next older forest surrounded by an additional 900 acres managed to maintain at least 50 percent in stands older than 30 years. The approach to protection and management of the sites varied by district, but generally harvest from commercial forestland within agreement sites was prohibited and other resource management allocations within sites carried harvest prohibitions as well. Later, in 1983, the BLM and Oregon Department of Fish and Wildlife (ODFW) agreed to establish 11 additional areas for spotted owl protection. The agreement was to remain in effect for 5 years, but was revised in 1987 to extend the expiration date until the planning process for the 1990s is completed in 1992, and to add 20 more agreement sites. This action constrained timber harvest on 230,400 acres around 110 owl locations throughout the five western Oregon BLM districts. The goal was to maintain a well-distributed population of 90 pairs of owls on land administered by the BLM. The actual number of sites was reduced to 109 with the

transfer of one area to the Grand Ronde Indian Reservation through congressional action. This reduced the total area protected to 228,000 acres, and no replacement area was designated.

In 1989, an additional 12 agreement sites were established under instructions to the BLM in section 318 of the Fiscal Year 1990 Interior and Related Agencies Appropriation Act (Public Law 101-121). This brought the total of owl management areas to 121, on which the BLM is deferring harvest on commercial forest stands. The guidance for establishment of these 121 areas was based on work by Forsman and Meslow (pp. 58, 59 in Gutiérrez and Carey 1985). They recommended 2,200 acres of forest more than 80 years old be designated for each site within a 3-mile radius of a known activity center of a single owl or pair of owls. Actual delineation of sites resulted in the acreage varying from 734 to 4,188 acres because of the range size of specific sites determined from radio-telemetry and lack of coniferous stands more than 80 years old.

Based on data collected between 1985 and 1990, the above management provided protection for approximately 20 percent of the known pairs of spotted owls on BLM lands. This plan was designed to provide for long-term maintenance of one pair in each site; however, it was concluded that additional pairs or singles may live within the boundaries of the designated sites.

In May 1990, the ISC released its report on a conservation strategy for the northern spotted owl. In September 1990, the BLM adopted the Jamison strategy, (named for the BLM's Director, Cy Jamison) (Jamison 1990) which incorporated the major elements of the ISC report and established the following guidelines for a 2-year period:

1. All current land use allocations under existing land use plans for uses other than timber management will be continued.

2. No regular green timber sales will be offered in proposed habitat conservation areas (HCA) category 1 through 4. All timber sales will be surveyed using BLM timber sale survey protocol, and any new owl pairs within the zone requiring category 3 HCA areas will be protected as per ISC report recommendations.

3. Salvage sales may be offered in HCAs if the action is to have no effect on the owl or its habitat, or if through consultation with the FWS the sale is cleared for harvest.

4. Forest management practices, such as tree planting on previously logged units, seedling maintenance, site preparation, precommercial thinning, and fertilization would also be permitted in the HCAs during the 2-year period.

5. No regular green timber sales will be offered in the 109 spotted owl agreement areas established under the 1987 agreement between the BLM and ODFW, or in the 12 additional areas established under section 318 of Public Law 101-121. Timber salvage sales may be offered in the ODFW agreement areas only after the concurrence of the ODFW.

6. In planning timber sales outside category 1 and 2 HCAs consider unit placement, to the extent possible, to reduce or eliminate the impact on the existing habitat conditions for those forestlands which have mean dbh of at least 11 inches and a canopy closure of at least 40 percent. The intent of this guideline is to provide dispersal habitat for owls.

7. Prepare a preharvest/postharvest profile of the habitat conditions in the forest matrix (forestlands outside category 1 and 2 HCAs) using quarter-township assessment areas to describe the percentage of the area in "stands with a mean dbh of at least 11 inches and canopy cover of at least 40 percent" condition. Include the profile narrative, figures, and maps as part of the BLM's biological assessment package on the fiscal year 1991 and 1992 annual timber sale plan that is submitted to the FWS for consultation.

8. Comply with the provisions of the Endangered Species Act relative to the spotted owl by consulting on all actions that constitute a "may affect" situation on the species or its habitat. Implement the mandatory terms and conditions in the FWS biological opinion to minimize incidental take of owls and habitat and, as appropriate, implement recommended conservation measures.

The Jamison strategy remained in effect until September 11, 1991, when the U.S. District Court in Eugene, Oregon, enjoined the BLM from implementing the strategy until the BLM complies with section 7 of the Endangered Species Act by submitting the strategy for consultation to the FWS. Management of BLM lands in Oregon will be based on existing timber management plans until completion of new resource management plans in 1992. This court decision did not affect management on BLM lands in California or Washington.

Resource Management Planning

In Oregon, the BLM currently is formulating alternatives for its western Oregon districts. Draft resource management plans and an environmental impact statement are scheduled for completion in early 1992. The BLM is considering five alternatives including one that would emphasize high production of timber and other economically important values on all lands to contribute to community stability; one that would emphasize protection of older forests values such as dispersed nonmotorized recreation opportunities and scenic resources; and one aimed at maintaining biological diversity, such as fish and wildlife habitat, recreation, and scenic resources on all lands. The BLM plans to analyze the effects of each alternative on spotted owls. The BLM, in cooperation with the Forest Service's Pacific Southwest Research Station Redwood Sciences Laboratory, is working to develop a spatially explicit life history simulator (model) for the relative assessment of impacts of management scenarios on the northern spotted owl.

Management of spotted owl habitat in California is confined to the Ukiah District office (Table 2.6). Current planning efforts for the Ukiah District, Arcata Resource Area, are focused on completing the record of decision for the resource management plan. The record of decision will defer any further green timber sales or disposal of lands containing old-growth habitat pending the completion of a state-initiated habitat conservation plan (HCP) for the owl. The Redding Resource Area recently released its draft resource management plan and is analyzing comments. Timber stands in the two resource areas are generally less than 300 acres in size and only rarely adjacent to other agency lands. Six tracts have been designated old-growth research natural areas or areas of critical environmental concern. The BLM Ukiah district manager is a member of the northern spotted owl HCP steering committee and two BLM scientists are members of the HCP scientific committee.

The BLM Spokane (Washington) District office manages approximately 3,000 acres of forestlands within the range of the spotted owl. Owl management has been limited to project clearance, surveys, and protection of suitable habitat within known owl activity areas. No nest sites are currently known.

Present Status of Habitat and Trend

The ISC and the 1990 status review (USDI 1990) both referred to the major factors influencing the amount and distribution of owl habitat on BLM land. The major factors identified include scattered and checkerboard land patterns; past land management activities (primarily timber harvest); and natural occurrences such as forest succession, wildfire, and windstorms. This has created a mosaic patchwork of stands more than 80 years old as habitat for spotted owls. These stand sizes range primarily from 50 to 500 acres, with some exceptions of 2,000 to 5,000 acres. The remainder of the landscape is in recent clear-cuts or forest stands ranging from 5 to 80 years old. Clear-cutting is the predominant harvest practice used by the BLM on lands in western Oregon. Both clear-cutting and selective harvesting have been used on lands in southwestern Oregon and northern California. Only limited use of silvicultural practices has been experimented with to create or maintain spotted owl habitat.

In past years, the BLM has classified forest stands older than 80 years as spotted owl habitat, using forest age classes, size, and crown closure as the main criteria. Because these attributes may not provide an adequate characterization of suitable owl habitat, the BLM refined its habitat figures using forest operations inventory data combined with a quality check by resource area biologists. Table 2.6 illustrates spotted owl habitat on BLM lands in western Oregon with two habitat component levels identified representing levels of habitat quality.

BLM lands in the Ukiah District, Arcata Resource Area, consist of isolated blocks generally 40 to 3,000 acres in size imbedded in a private landscape. The private lands have been subjected to extensive harvest during the last decade and contrast with the older timber stands on the adjacent public lands, where most of the remaining owl territories are found.

Clear-cutting has not been practiced in the Ukiah District since 1981. Starting in 1982, the BLM has practiced the managed old-growth concept of forestland management on all timber sales. These guidelines provide for at least 10 percent of the site's potential basal area to be occupied by trees that have survived at least two 100-year rotation cuttings. These superdominant trees provide a base for future recruitment of snags and down debris. The structural elements of old-growth management include 1) large trees for shade and reproduction, 2) large snags for nesting, 3) large debris for nitrogen fixation and carbon recycling, and 4) coarse woody debris in the headwater areas of drainages for erosion control.

Estimates were made in the 1990 status review (USDI 1990) predicting the rate of decline of habitat during the next 10 to 50 years on BLM-administered land. Historic data showed a loss of approximately 475,000 acres during the last 20 years. Assuming the harvest rates prior to the listing of the owl, habitat would have been extremely limited within 30 years. However, since the 1990 listing, the actual timber sale level has been reduced to approximately 40 percent of

recent historical levels. This change is based on congressional direction and FWS biological opinions on BLM timber sales. Future figures could be reduced to even lower levels. However, BLM forestlands harvested in the late 1960s and early 1970s could be expected to begin providing limited spotted owl habitat in the next 50 to 60 years.

Inventory and Monitoring

The BLM in Oregon has been surveying its lands for spotted owls since the early 1970s. The percentage of BLM lands that have been inventoried by district ranges from 50 to 90 percent. Early inventories were neither complete nor uniform, although data were accumulated on historic locations of owls across the land base. After the completion of land use plans in 1983, a comprehensive monitoring plan was developed for Oregon and was put into operation in 1986. This has resulted in more consistent and complete data collection among districts. When surveys found and verified new locations, these were added to the list of sites to be monitored. The process is based primarily on locating and tracking owls over time. Oregon data from the period of 1988 through 1990 showed that 518 pairs were verified on BLM lands in western Oregon. Single owls or unconfirmed pairs were present at an additional 110 locations during this same period. More than 60 percent of the owls found were in the Roseburg and Medford Districts.

The BLM also implemented an intensive banding program in 1985 to mark individual owls. Through 1990, more than 1,800 owls were banded, nearly a third of them were juveniles. Results from the banding information will provide insights into longevity, movement, survival, and age at first breeding.

Inventories of northern spotted owl habitat in California since 1977 have been conducted as needed to survey timber harvest plans or other major land use actions. Complete documented survey data have been maintained only since 1988. With about 25 percent of the habitat surveyed in the Ukiah District, 20 pairs of owls (17 in the Arcata Resource Area and three on the Redding Resource Area) have been detected on BLM lands in California since 1988. Thirty percent of known spotted owl territories (7 of 17) in the Arcata Resource Area have been monitored continuously since 1987 by researchers from Humboldt State University, but no comprehensive monitoring program has been developed yet for California.

Applicable Law

The principal legislative mandates guiding management of these lands are derived from the O&C Act and the Federal Land Policy and Management Act (FLPMA). The O&C Act applies exclusively to lands in western Oregon, generally configured in an alternate-section checkerboard pattern. The O&C Act directs management of these lands for sustained-yield permanent forest production that contributes to economic stability of local communities and industries. In addition, other management requirements are for permanent timber supply, protection of watersheds, regulating stream flows, and providing recreation facilities. FLPMA provides multiple-use management direction and overall resource-management planning requirements for all lands administered by the BLM.

3. National Park Service

The following areas managed by the National Park Service (NPS) are known to contain northern spotted owls: North Cascades, Mount Rainier, and Olympic National Parks in Washington; Crater Lake National Park and Oregon Caves National Monument in Oregon; and Redwood National Park, Point Reyes National Seashore, and Muir Woods National Monument in California. Whiskeytown National Recreation Area in California also may be occupied by northern spotted owls. These areas provide up to 570,000 acres of suitable habitat, although none has been surveyed for owls. The NPS currently has no coordinated inventory and monitoring program for spotted owls.

Management Background

Management of areas of the NPS is generally compatible with that required for recovery of the northern spotted owl. In fact, Barry (1990) suggested that few environmental laws are more consistent with NPS objectives than the Endangered Species Act. The primary purpose of the act is to preserve for future generations endangered and threatened species and the ecosystems upon which they depend, while the goal of the NPS is to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations," (NPS Organic Act).

The policy of the NPS is to manage natural resources "with a concern for fundamental ecological processes, as well as for individual species," (NPS Management Policies 1988:4:1) as well as "identify and promote conservation of all federally listed threatened, endangered, or candidate species within park boundaries and their critical habitats." Active management programs will be conducted as necessary to perpetuate the natural distribution and abundance of threatened or endangered species and the ecosystems on which they depend (NPS Management Policies 1988:4:11).

Management actions will be in accordance with, and follow recovery priorities identified in approved recovery plans (NPS 1991:273). Habitat manipulation, species restoration, or population augmentation are "encouraged if identified as appropriate in the recovery plan and if such activities would result in a more representative distribution of the species within the park," (NPS 1991:274). Such management activities must "consider potential impacts on other native species" and "significant modification of habitat and landform is discouraged unless necessary to prevent extirpation or extinction of the species" (NPS 1991:274). All management actions for endangered or threatened species will be described and assigned priorities in the park's approved resources management plan.

Applicable law

The general authority under which the NPS operates is the NPS Organic Act (16 USC 1), which authorizes the NPS to "regulate the use of the federal areas known as national parks." See the statement of purpose of this act earlier in this section.

Each park also has its own enabling act. Congress has stated in the enabling legislation of most units that they have their own particular purposes and objectives. These may be broad or very specific. For example, Crater Lake was established in 1902 "as a public park or pleasure ground for the benefit of the

people of the United States." Redwood National Park, created in 1968, was established "to preserve significant examples of the primeval coastal redwood forests and the streams and seashores with which they are associated for purposes of public inspiration, enjoyment, and scientific study."

The Endangered Species Act applies to all national park system areas as it does to other federal lands.

4. Fish and Wildlife Service

Management Background

The U.S. Fish and Wildlife Service (FWS) administers several national wildlife refuges within the range of the owl. Two refuges in Oregon and two in Washington contain small parcels of suitable owl habitat. National wildlife refuges are managed in accordance with goals of preserving a natural diversity and abundance of fauna and flora on refuge lands and of preserving, restoring, and enhancing in their natural ecosystems all endangered and threatened species of animals and plants.

Since the northern spotted owl was proposed for listing, the FWS has conducted hundreds of conferences and consultations under section 7 of the Endangered Species Act concerning the land management activities of federal agencies within the species' range. Since publication of the proposal to designate critical habitat, the conference process also has been available with regard to effects of federal management on the areas proposed for designation. With final designation of critical habitat on January 15, 1992, consultation responsibilities were extended to these areas so designated.

Applicable Law

The FWS assists other federal agencies in fulfilling their obligations under section 7 of the Endangered Species Act. The act requires agencies to undertake programs for the conservation of endangered and threatened species and to ensure that their actions are not likely to jeopardize the continued existence of a listed species or to destroy or adversely modify its critical habitat. Agencies must consult with the FWS on any action that may affect a listed species.

Consultation. The FWS conducts consultations at the request of an action agency to determine whether actions proposed by federal agencies are likely to "jeopardize the continued existence" of threatened or endangered species, or result in "destruction or adverse modification" of critical habitat designated for listed species. These phrases are defined in regulations (50 CFR 402.02) as follows:

> "*Jeopardize the continued existence* means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species."

> "*Destruction or adverse modification* means a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. Such alterations include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical."

The results of a consultation are summarized by the FWS in a biological opinion. During the consultation, the FWS estimates the amount of take of listed species that will occur incidental to the action. If the proposed action would result in incidental take, then the FWS may develop "reasonable and prudent measures" to minimize the level of take. The biological opinion states whether incidental take is authorized (assuming the reasonable and prudent measures are followed), and describes the permissible level of take. The description of allowable take is called an incidental take statement.

If the FWS concludes that the action is likely to jeopardize a species, or lead to the destruction or adverse modification of critical habitat, then the FWS attempts to work with the action agency to develop reasonable and prudent alternatives. Reasonable and prudent alternatives are designed to allow the action to continue without jeopardizing the continued existence of the species or resulting in the destruction or adverse modification of critical habitat.

> "*Reasonable and prudent alternatives* refer to alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the federal agency's legal authority and jurisdiction, that is economically and technologically feasible, and that the director believes would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat." (50 CFR 402.02.)

Agencies are required by the Endangered Species Act to follow the provisions of the incidental take statement and to implement the reasonable and prudent measures. The act also requires agencies to avoid jeopardizing any listed species or causing destruction or adverse modification of critical habitat. Agencies may act on their own conclusions, however, about whether a proposed action will have any of these effects; they do not have to accept the judgement of the FWS. Therefore, once consultation is complete, agencies may proceed with the action regardless of the outcome of the consultation as long as they follow the provisions of the incidental take statement and the reasonable and prudent measures (if any).

Further consultation is not required except in the following situations:

> "Federal involvement or control over the action has been retained or is authorized by law and:
>
> a) If the amount or extent of taking specified in the incidental take statement is exceeded;
> b) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered;
> c) If the identified action is subsequently modified in a manner that causes an effect to the listed species that was not considered in the biological opinion; or
> d) If a new species is listed or critical habitat designated that may be affected by the identified action." (50 CFR 402.16)

When a species has been proposed for listing or an area has been proposed for designation as critical habitat, a similar procedure, known as conference, is required. A conference results in an advisory report to the action agency, but does not provide an opinion regarding the likelihood of violation of section 7.

The FWS also enforces the Endangered Species Act's taking prohibitions and participates in conservation planning. Development of a conservation plan

that satisfies the act's requirements can be the basis for issuance of incidental taking permits to nonfederal land managers.

Prohibition against take. After the northern spotted owl was listed as a threatened species, private timberland owners requested guidance from the FWS on how they could harvest timber without violating the Endangered Species Act. Since the only requirement of nonfederal entitites under the Endangered Species Act is the prohibition against take, the FWS issued guidance on the measures needed to avoid taking owls. The FWS believes, however, that the "survey and circle" approach described in that guidance does not provide adequate long-term protection for the subspecies. In addition, the FWS is concerned about the substantial costs being incurred by landowners providing these protective measures. One of the goals of the Recovery Team is to develop more efficient ways by which landowners may provide equal or increased protection for owls while incurring equal or lower economic costs. Some of the concerns about the take circles are described below.

1. Biological concerns.

- Although the take circles are a uniform size within a province, their contribution to recovery is variable. They differ in the amount and quality of suitable habitat they contain and in their placement across the landscape. Yet, the circles are protected equally, regardless of their actual contribution to recovery.

- Application of the take guidelines tends to encourage fragmentation of habitat. Landowners also have an incentive to cut habitat before an owl is found, reducing that habitat in the near term.

- The amount of habitat in the take circles is not optimal for recovery of the species.

- The spacing of the take circles is not optimal for contributing to recovery. The circles surround owls where they are currently located and, in some cases, they are spaced too far apart to allow for successful dispersal among them. Some circles overlap, creating clusters of pairs helpful in recovery, while other circles are isolated from the rest of the population by large expanses of unsuitable habitat.

- The take prohibition works most effectively to protect habitat where owls are most numerous, and does not effectively protect habitat, such as linkages among federal lands, in areas which currently do not contain owls.

- Surveys conducted to comply with the take prohibition provide only a portion of the data required for monitoring owl recovery. Surveys are generally conducted in areas of planned timber harvests and, though the results contribute to the assessment of owl populations, the surveys provide little information about habitat or population trends at the landscape level.

2. Land management concerns.

- Discovery of an owl forces the creation of another restricted harvest circle, and may result in unexpected decline in income. This serves as a disincentive for landowners to survey or provide owl habitat.

- Since landowners already face cutting restrictions within the take circles, they may hesitate to contribute what they perceive to be additional habitat toward conservation of the population.

- Compliance with surveys and circles is costly and limits landowners' ability to plan timber harvest schedules.

- Landowners are skeptical that a negotiated agreement to allow take under specified conditions will be as advantageous as simply complying with current take guidelines. Landowners also may perceive that the basis for a negotiated agreement is their current owl protection contribution, which they may perceive as excessive.

- Many landowners disagree with the FWS's interpretation of when take is likely to occur. The recent administrative recision of the take guidelines for strictly procedural reasons has further led to the perception that the definition of take is unclear and uncertain. This hampers predictability of owl protection and land management.

- Mechanisms under the Endangered Species Act for authorizing take differ for federal and nonfederal parties. Nonfederal landowners face a more arduous and lengthy process, which includes formal public review, for receiving take authorizations than do federal landowners. Even when spotted owl circles are centered on federal land and the federal agency is given an incidental take permit for that owl, nonfederal landowners within that circle cannot receive permission to harvest until the landowners write protective management plans (under section 10 of the act) or until the FWS writes "special rules" allowing take under section 4(d).

The success of the prohibition against take in contributing to recovery is variable, and is dependent upon the province and existing conditions within owl home ranges. It is also dependent upon the application of the take prohibition guidelines by state regulators and the FWS. Each state has a different ability and capacity to apply the take guidelines based on differences in their regulatory frameworks.

Habitat Conservation Plans. The Endangered Species Act generally prohibits the "taking" of listed species. Take is defined in part as harm, harassment, or killing individuals of the species. Destruction of the species' habitat which ultimately results in harm or harassment to the species may also constitute a taking under the act. Prior to 1982, the only activities that could be exempted from the prohibition against take were scientific research, captive breeding, and similar conservation actions. In 1982, the act was amended to permit taking "if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity". In permitting such "incidental take," Congress hoped to reduce conflicts between listed species and private development and to encourage "creative partnerships" between the private sector and local, state, and federal agencies in the interest of endangered species and habitat conservation. An applicant for an incidental take permit must agree to institute appropriate conservation measures for habitat maintenance, enhancement, and protection, described in a habitat conservation plan (HCP). The FWS reviews the HCP and, before issuing a permit for the incidental take, must find that (1) the taking will be incidental; (2) the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking; (3) the applicant will ensure that adequate funding for the plan will be provided; (4) the taking will not appreciably reduce the likelihood of survival and recovery of the species in the wild; and (5) other measures that FWS may require will be met.

5. State of California

Regulatory Programs

Forest Practices Act. The Forest Practices Act established a comprehensive system for the regulation and management of timberlands to assure that productivity is restored, enhanced, and maintained, and that the goal of maximum sustained production of high quality timber products is achieved while giving consideration to watershed, wildlife, recreational, and other important values related to forest ecosystems. The program applies to more than 7 million acres of state and private timberlands.

Rules adopted by the California Board of Forestry implement the provisions of the Forest Practices Act and the requirements of other statutes, such as the California Environmental Quality Act.

The forest practices regulatory programs and review process for timber harvest plans (THP) have been certified by the Secretary of Resources as functionally equivalent to environmental impact report and analysis under the California Environmental Quality Act. Before timber harvesting may commence, the Department of Forestry and Fire Protection must review and approve a THP which discloses information on the proposed timber harvest operation and its effects on the environment. A timber harvest plan may not be approved as proposed if there are feasible alternatives or mitigation measures available that would substantially lessen any significant adverse environmental impacts from implementation of the proposal.

1. Silvicultural Requirements

   A THP must indicate which selected silvicultural methods are appropriate to the site conditions to protect environmental values. The plan is subjected to a review process that includes consultation with other departments, such as the Department of Fish and Game and California Water Quality Control Boards, and public review and comment.

2. Sensitive Species Listing Process

   The California Board of Forestry identifies by regulation plant and animal species or subspecies that require special consideration in the review of THPs to avoid damage to their habitat areas. The process is similar to the listing process specified under the California Endangered Species Act.

   The state forestry board regulations include specific requirements for protecting these species. The northern spotted owl is among the species for which these requirements apply.

3. Water Course and Lake Protection Zones

   The water course and lake protection rules ensure protection of the water quality, beneficial uses, and biological characteristics of watercourses and lakes within timberlands. Within fixed protection zones timber operators are restricted or constrained (e.g., by prohibition of clear-cutting and limits on road building) to prevent discharge of materials and erosion in and around watercourses and lakes.

4. Cumulative Effects Assessment

The preparation of a THP must include an assessment of potentially significant cumulative impacts from the proposed timber harvest operation for a number of environmental variables. The assessment process must indicate whether the proposal, when considered with the impacts of past projects and reasonably foreseeable future projects, would result in significant adverse environmental impacts.

Evaluation of cumulative effects on biological resources includes identifying resources of concern, such as threatened and endangered species, sensitive species, important wildlife resources such as game animals, and specific components of wildlife habitat.

Mitigation measures and other protection are included in THPs as needed to avoid, reduce, or offset significant adverse cumulative effects. Direct and indirect effects resulting from the proposed action must be addressed. While the rule does not contain specific mitigation requirements, it does provide an analytical basis for requiring site-by-site protection if needed.

Evaluating potential timber harvesting impacts to northern spotted owls in the analysis of cumulative effects provides several benefits for owl conservation: 1) the impacts of a proposed timber operation are assessed in the context of past, present, and future projects in the same area; 2) impacts are assessed on broader temporal and spatial scales than those addressed by individual THPs and an assessment limited to direct impacts; and 3) the assessment process tailors the analysis to fit unique conditions of owl populations and habitat, information availability, and perceived threshold of impacts.

5. Specific Northern Spotted Owl Rules

The state forestry board has adopted specific rules for the protection and conservation of the northern spotted owl (emergency rules in August 1990; permanent rules in February 1991), which are designed to prevent take of northern spotted owls. Approval of any harvest plan that would cause significant long-term damage to the owl must be withheld. Other rules require a THP to provide specific information about owl habitat and owls within the proposed harvest area and adjacent areas. The California Department of Forestry and Fire Protection and the California Department of Fish and Game have developed a procedure whereby plans are reviewed and a determination is made whether the plan will result in a take. This process has the concurrence of the FWS.

6. Nonindustrial Timber Management Plan

As an alternative to THP review, the state forestry board has adopted rules to permit nonindustrial forestland owners holding less than 2,500 acres to submit long-term management and harvesting plans. The plans are required to prescribe uneven-age management of the forestland. The owner must submit management information regarding silvicultural methods, harvest scheduling, existing and future stand conditions, and other pertinent information. Using this option, spotted owl conservation needs can be integrated with timber harvesting and management of nonindustrial timberlands.

California Environmental Quality Act (CEQA). The CEQA is similar to the National Environmental Policy Act; before state or local agencies may approve

or undertake any project that may result in significant environmental impacts, they must review and disclose the potential impacts, adopt feasible mitigation measures, and adopt findings regarding the impacts of the proposed project.

California Endangered Species Act. The California Endangered Species Act of 1984 established a process whereby the public or the Department of Fish and Game may submit a petition to the Fish and Game Commission with a recommendation to list (or delist) as threatened or endangered, any native species or subspecies of plant or animal.

If a species is considered a candidate for listing, restrictions on import, export, take, possession, purchase, or sale go into effect. If the species is listed, additional restrictions regarding jeopardy, consultation with California lead agencies, required mitigation measures and commitment to conservation, protection, and enhancement go into effect. The northern spotted owl is not currently listed as a threatened or endangered species under this act.

Land Management

State Parks. Lands within state parks are administered by the California Department of Parks and Recreation to protect and perpetuate natural resource systems and values. Commercial resource development, including timber harvesting, is not permitted in state park units. There are 27 state park system units in the northern coastal portions of the owl's range. Eighteen of the units are known to support at least one owl territory. The Department of Parks and Recreation is participating in the California habitat conservation plan efforts for the northern spotted owl.

State Forests. The California Department of Forestry and Fire Protection administers the state forest system in accordance with a management plan approved by the state forestry board. The Jackson Demonstration State Forest is within the range of the northern spotted owl. It encompasses 50,000 acres that are used for demonstration and research experiments addressing fish and wildlife conservation needs, watershed protection measures, recreational uses and commercial timber harvesting. The state forest is completing a spotted owl and small mammal survey. Harvesting operations fall under the Forest Practices Act and must comply with all forest practices rules, including those prescribing protection for northern spotted owls under that act.

Protection from Fire. The California Department of Forestry and Fire Protection has primary responsibility for fire prevention and protection for the 32 million acres of state-responsibility lands. The department is responding aggressively to growing fire risks associated with prolonged drought and the movement of a significantly larger number of people to rural California. The department is particularly aware of the need to reduce the risk of large, catastrophic fires, such as those likely to affect conservation measures for the northern spotted owl.

Forestry Assistance. A number of forestry assistance programs for private landowners is coordinated through the Department of Forestry and Fire Protection, including the California Forest Improvement Program and the Federal Forest Improvement Program. These programs share costs of tree planting and forest management on nonindustrial forestland ownerships. These programs benefit the northern spotted owl by providing another means of establishing habitat over time on lands that might otherwise not be restored or might be converted to nonforest uses.

Timberland Task Force. The Timberland Task Force was established in January 1990, pursuant to legislative direction (Assembly Bill 1580) to develop a long-term, more comprehensive, process for addressing wildlife issues in the context of forestland management. The Timberland Task Force is charged with developing a coordinated base of scientific information for analyzing cumulative impacts on the biological diversity of forestland ecosystems, evaluating timberland habitat for its contribution to the overall maintenance of specific wildlife species, contracting for studies to validate wildlife models and develop mitigation, and identifying critical habitat areas and species of special status. The task force includes representatives from state and federal agencies.

The task force will report its recommendations to the governor and California legislature in 1992. The coordinated database will be used in reviewing individual timber harvest plans with regard to their cumulative impacts on wildlife. The database will include geographic information system (GIS) analysis of vegetation and habitat on forestlands (a pilot vegetation/habitat mapping project covering approximately 6 million acres within the range of the northern spotted owl will be completed in early 1992) and linkage with the state's Wildlife Habitat Relationships Database (WHR) to relate vegetation growth and yield models to possible land management options.

Developing from the initial work of the Timberland Task Force, a memorandum of understanding establishing an executive council to set guiding principles and policies regarding statewide efforts to conserve biological diversity was signed on September 19, 1991. This memorandum will provide the long-term framework for developing a statewide strategy to conserve biological diversity and coordinate implementation through regional and local institutions.

The Statewide Executive Council, chaired by the Resources Agency Secretary and consisting of state and federal agencies, will set statewide goals for the protection of biological diversity, and will encourage and assist the establishment of bioregional councils to achieve protection of biological diversity. Under this umbrella, a Klamath bioregion project addressing the range of the northern spotted owl in California is developing, and will build on the state habitat conservation plan.

Habitat Conservation Plans. The California Board of Forestry and Fire Protection initiated the state's habitat conservation planning (HCP) for the northern spotted owl in November 1990, anticipating a future application for an incidental take permit under the federal Endangered Species Act. This effort is in addition to the adoption of rules to ensure that timber harvesting on state and private lands in California would not result in a take of northern spotted owls.

The HCP and the associated environmental impact report/environmental impact statement are being developed under the guidance of a broadly based steering committee appointed by the state forestry board.

The steering committee operates under a set of objectives intended to promote development of a plan that fully meets the requirements of the federal Endangered Species Act while also limiting effects on private landowners and economic impacts.

The steering committee and a scientific committee currently are evaluating eight options, which resulted from extensive public scoping efforts and repre-

sent a range of levels of protection for the owl. The alternatives have been developed with the assumption that a comprehensive owl conservation strategy, such as the ISC proposal, would be implemented on federal lands. A draft HCP and associated environmental review documents are expected to be available for public review by May 1992.

Forest and Rangeland Resources Assessment Program. The Forest and Rangeland Resources Assessment Program (FRRAP) was established in 1978. The charge of the program is to describe and analyze the current conditions of California's forest and range resources base and to anticipate emerging management problems that require public or private action. The FRRAP is involved in a number of efforts related to spotted owl conservation, including long-term monitoring of forestland condition through periodic mapping; development of a statewide geographic information system for assessing impacts, uses, and trends; development and use of long-term timber harvest simulators that also track impacts on wildlife habitat; and economic impact estimation. The FRRAP provides primary staff to the Timberland Task Force and HCP efforts.

California Natural Diversity Data Base. The Department of Fish and Game maintains the California Natural Diversity Data Base, a computerized inventory of the locations and condition of endangered, threatened, and rare animal and plant taxa, as well as significant terrestrial and aquatic plant communities which was developed in cooperation with The Nature Conservancy. Project proponents and agencies consult the data base during project development and during the environmental review of various land management activities under the provisions of CEQA. Detailed northern spotted owl sighting information is maintained in an associated data base that is accessed on a "need to know" basis.

Natural Community Conservation Planning. Recent California legislation has established the natural community conservation planning (NCCP) process to meet the needs of threatened and endangered species and to provide protection for significant areas that support natural ecosystems and biological diversity. A memorandum of understanding signed on December 4, 1991, between the FWS and the State of California (Resources Agency and Department of Fish and Game) provides for sharing data and cooperatively developing an NCCP pilot program in southern California.

6. State of Oregon

Oregon has regulatory programs, technical assistance programs, land management objectives, and research that are aimed at conservation efforts for the northern spotted owl.

Regulatory Programs

Forest Practices. The Forest Practices Act (FPA) was enacted to assure the continuous growing and harvesting of forest tree species while protecting soil, air, wildlife, and water resources on 10.1 million acres of private, state, and county forestlands. It regulates commercial forest operations to ensure forest practices that maintain and enhance the benefits of all forest resources.

Under the FPA, threatened and endangered fish and wildlife species are inventoried. This resource inventory will be used to inform forest landowners of their obligation to protect the owl; furthermore, it may help local government protect some natural resource sites in compliance with Oregon's land use laws.

Spotted owl nesting sites and activity centers are protected under the FPA rules. Proposed and ongoing forest operations within 1 mile of a spotted owl nest site or activity center must obtain approval of a written plan from the Oregon Department of Forestry before proceeding. Harvest operations must leave a core area comprising 70 acres of the best available habitat in the vicinity of a nest site. The Oregon Department of Fish and Wildlife (ODFW) provides site-specific assessment and advice to landowners when owl sites are identified on nonfederal lands. Overall, forest practices that would significantly reduce suitable habitat in the core area are not allowed. Forest practices that would disturb owl nesting behavior and possibly result in nest failure must not be carried out during the breeding season. In addition to complying with the provisions of the FPA, landowners also must comply with the federal Endangered Species Act.

Oregon Endangered Species Act. The northern spotted owl is listed as a threatened species under Oregon's Endangered Species Act. This act authorizes the Oregon Fish and Wildlife Commission to conduct research, census, law enforcement, propagation, transplantation, and habitat acquisition and maintenance for listed species. Agencies must consult with the ODFW before taking any action that may harm owls on state-owned lands.

Statewide Land-Use Planning Program. The State of Oregon has an extensive program for land use planning. While it is not the first or only statewide planning effort, it is one of the most comprehensive. The program has many aims and objectives, but the most important ones relating to protection of threatened and endangered species are contained in Goal 4 (Forest Lands) and Goal 5 (Open Spaces, Scenic and Historic Areas, and Natural Resources) of the program.

Land Management

Department of Forest Land Management. The Oregon Department of Forestry is responsible for the management of nearly 786,000 acres of forestland to secure the greatest permanent value to the state. Production of timber on a sustained-yield basis is established as the primary goal, but due consideration must be given to all other appropriate uses of the land.

Of the 786,000 acres managed, 654,000 acres are Oregon Board of Forestry lands (county trust lands) and 132,000 are Common School lands. Aside from timber harvesting, the state forester is authorized to permit other forest uses such as recreation, watersheds, and fish and wildlife conservation. Those lands which, in the opinion of the state forester, have exceptional scenic and/or fish or wildlife habitat values, and on which commercial forest management would significantly degrade those values, are classified as "conservancy." Twenty-six thousand acres of Oregon forestland are classified as conservancy and reserved from timber management. Another 24,000 acres of state forestland are classified as noncommercial (not capable of sustaining timber harvesting) and also are withdrawn from timber harvesting.

Land Acquisition, Sale, and Exchange. The Oregon Board of Forestry acquired title to lands during the 1930s and 1940s from counties that had foreclosed on the lands for nonpayment of taxes. There is an implicit trust arrangement with the counties requiring payment to the counties of a share of the revenues generated by the land-management activities conducted on these lands. More than two-thirds of these lands are in the Tillamook State Forest, located primarily in Clatsop and Tillamook Counties. The county court or board of county commissioners of any county in which such land is situated also must approve exchanges; only after this approval may the exchange be consummated.

Under Oregon law, the primary objectives for managing Oregon Board of Forestry lands are to 1) generate revenue for county governments and local taxing districts; 2) make raw materials available on a sustained-yield basis to help meet demands for forest products; 3) obtain the greatest permanent value for Oregon; 4) provide community stability; 5) encourage efficiency in harvesting and processing; 6) encourage full economic utilization of the forest resource; and 7) provide employment.

The State Land Board holds title to the Common School lands. About two-thirds of the acreage are located within the Elliot State Forest in Coos and Douglas Counties, with the the balance scattered in 30 other counties. The state forester manages the Common School lands under a contract with the State Land Board. The primary objective for the management of these lands is to generate income for the Common School Fund consistent with sound land and timber management practices. The State Land Board and the Oregon Board of Forestry each are required separately to approve exchanges by resolution.

Forestry Assistance. This program helps Oregon's private forest landowners meet their resource management objectives. This includes increasing forest growth and harvest potential to help ensure future supplies of timber and other forest products, promoting forest health, and enhancing and protecting fish and wildlife, soil, air, water, recreation, and aesthetics. Technical advice on applying the principles of integrated pest management, minimizing disease mortality and growth loss, forest management, and wildlife enhancement is provided upon request to private forest landowners.

Other Public Forestlands. Oregon's state parks include 74,000 acres of forestland withdrawn from timber production. Some of Oregon's parks, including Silver Falls and Saddle Mountain State Parks, provide suitable habitat for northern spotted owls. Several of the coastal state parks adjacent to federal lands may provide additional habitat.

The ODFW owns 30,000 acres of forestland devoted to producing wildlife habitat. County and municipal governments also have withdrawn 36,000 acres of their 146,000-acre timberland base.

Wild and Scenic Rivers. The federal Wild and Scenic Rivers Act designated 40 rivers in Oregon for inclusion in this system. Additional segments of these and other rivers are protected by the Oregon Scenic Waterways Act, administered by the Oregon Parks and Recreation Department. The Oregon Scenic Waterways Act protects the character of the rivers for fish, wildlife, and recreation.

Governor's Watershed Enhancement Board. The Governor's Watershed Enhancement Board provides technical assistance and grants for projects that focus on improvements to streams and upland areas of watersheds. These improvements, such as the enhancement of riparian areas, also may provide some owl habitat.

Research

Oregon Department of Fish and Wildlife is engaged in a project to assess the viability of northern spotted owl pairs on state-owned lands. Researchers are banding owls to track them over time. The focus of the study is spotted owl turnover and reproductive rates.

Coastal Oregon Productivity Enhancement (COPE) Program is a cooperative research effort among several groups, including the Forest Service's Pacific Northwest Experiment Station and the College of Forestry at Oregon State University. Among the goals of the COPE program are conducting large-scale operational testing of forest management strategies, developing methods to assess the effect of various riparian and reforestation management systems on water, timber, and wildlife, and making scientific information more accessible to forest managers in the region. The COPE program currently has proposals to study several nontraditional silvicultural methods for simultaneously producing timber and wildlife values.

Oregon State University's College of Forestry's research forest is being used by a group of researchers to conduct a study entitled *New Perspectives for Management of Timber and Mature-Forest Wildlife in Douglas-fir Forests.* Researchers are examining different silvicultural systems that might enable foresters to manipulate stands to produce the kind of habitat needed by interior-forest species like the spotted owl.

7. State of Washington

Existing programs in Washington contributing to or having the potential to contribute to owl conservation include forest practices and land use regulations, management of state-owned lands, land acquisition, research, and various landowner assistance or incentive programs. In the past 2 years, considerable efforts have been made that have benefitted spotted owls through administration of forest practices regulations and cooperative planning for certain state-owned lands.

Regulatory Programs

State Forest Practices Act and Regulations. The Forest Practices Act and its implementing regulations are intended to afford protection to forest soils, fisheries, wildlife, water quantity and quality, air quality, recreation, and scenic beauty, coincident with maintenance of a viable forest products industry. The regulations, administered by the regulatory branch of the Department of Natural Resources, apply to 12 million acres of state and private land.

Timber harvest, road construction, and chemical spray on "lands known to contain a breeding pair or the nest or breeding grounds" of a federally listed species, or within the federally designated critical habitat of such species are subject to review under the State Environmental Policy Act (SEPA). "Lands known to contain" currently is interpreted to include all occupied suitable habitat subject to federal prohibitions on taking.

SEPA review entails information gathering, including owl surveys, and findings as to significant adverse environmental impacts. Surveying protocols and interpretation of results are provided by the Washington Department of Wildlife, which also maintains a data base documenting locations of all known owl sites in Washington.

Substantive forest practice permit decisions under SEPA require a balance between avoiding or mitigating identified adverse impacts and maintaining a viable forest products industry. Therefore, while state permit decisions currently reflect the biological thinking that was embodied in take guidelines adopted by the FWS, decisions may diverge from those guidelines in some respects. Nevertheless, state permittees are not relieved of any responsibilities

they may have under federal law. Several hundred permit applications were affected in some way during 1990 by Washington regulatory requirements related to the northern spotted owl. The regulations also provide protection to nontimber resources, including wildlife habitat, within designated riparian areas.

Washington Environmental Policy Act. This law is similar to the National Environmental Policy Act. Implementing regulations require environmental analysis and public review, and set substantive environmental goals for all agencies.

Local Zoning and Land Use Control. Local government permits are required for land use conversion, clearing and grading, and building construction. Permits generally are subject to SEPA analysis.

Wildlife Laws. Pursuant to Washington's wildlife laws, the state Wildlife Commission may by rule designate a species of wildlife as endangered. Hunting of or trafficking in endangered wildlife species is prohibited. The northern spotted owl is listed as endangered under Washington law.

Land Management

State Lands—Federally Granted Trusts. These lands were granted to Washington by the federal government to be managed in trust for the financial benefit of schools and other legally designated beneficiaries. About 1.3 million acres of forestland are currently in this ownership. Common law requires the state, acting through the Department of Natural Resources, to exercise the same prudence a private person would exercise in managing his or her own land. Case law requires undivided loyalty to the trust beneficiaries. Forested trust lands are managed on a sustained-yield basis. Trust lands are subject to the same regulatory requirements as those of other landowners. Beyond regulatory requirements, wildlife habitat objectives are incorporated into management, consistent with trust requirements.

State Lands—Forest Board. State statute created this state ownership of approximately 620,000 acres. These lands, mostly second-growth, are dedicated to perpetuate the forest resource. Revenues from management benefit county junior taxing districts and the state general fund. Case law indicates that the state has a trust relationship to county beneficiaries.

Commission on Old-Growth Alternatives. In June 1989, this broad-based citizens' commission made consensus recommendations to the Department of Natural Resources on management of old-growth forest on state lands on the western Olympic Peninsula. Recommendations included a 15-year harvest deferral on 15,000 acres of the most critical owl habitat, acquisition from the trusts of 3,000 acres of land with high ecological value, creation of a 260,000-acre experimental forest and a forest research center, and calculation of a sustained-yield level for these lands distinct from other state lands. These proposals are in various stages of consideration and implementation.

Industrial Lands. This is the largest nonfederal forestland ownership category in Washington, responsible for more than half of the total state timber supply in recent years. Although managed to provide economic returns, industrial lands are subject to the state forest practices regulations described earlier. In some cases, relatively large contiguous ownership blocks are conducive to effective voluntary management for some nontimber values,

including wildlife. In other cases, scattered or checkerboard ownership with federal lands complicates management.

Nonindustrial Private. Nonindustrial lands comprise almost a quarter of the forestland ownership in Washington. These lands may or may not be managed primarily for timber. Because of their location close to human populations, management of these lands has important effects on supply of nontimber values. However, due to their small size and generally young timber, opportunities for management of these lands to promote owl conservation are limited.

Land Acquisition

Washington Wildlife and Recreation Coalition. Created in 1988 as a coalition of citizen groups, this organization lobbies the state legislature for funds to bring high priority habitat and park lands into public ownership. To date, $113 million have been appropriated for these purposes.

Trust Land Purchase Program. In 1989-90, the Washington legislature appropriated approximately $150 million in state general funds to purchase environmentally sensitive state trust lands. When completed, these purchases will bring about 60,000 acres into conservancy management. The value of the timber (usually about 90 percent) goes to the same trust accounts as does timber sale revenue. The land value goes to purchase replacement trust lands.

Other Preserved Lands. Several hundred thousand acres of state lands are managed in a preserve status as natural area preserves, state parks, wildlife areas, and under related designations. Periodically additional lands are added to these categories. Some of these lands may contribute to owl habitat, but for the most part, they are of small individual size.

Assistance Programs

Washington provides a number of programs of technical and financial assistance to small-acreage forest landowners to encourage improved management of lands for a variety of objectives, including timber supply, watershed protection, and wildlife habitat. In the future, additional funds are expected to be available to address a broader range of resource objectives.

Incentive Programs

Several programs of state and local government currently provide a variety of tax and other incentives for land management that promote open space, farmland preservation, and other resource objectives. These programs may contribute incidentally to owl conservation, but would need expansion and direction to make more substantive and intentional contributions.

Research

The Department of Natural Resources and the Department of Wildlife conduct and participate in research programs concerned with the spotted owl. For the most part, these research programs are funded and led by federal resource agencies.

8. Indian Land

Indian reservation lands have been set aside for the exclusive use and benefit of Indian people pursuant to treaties, statutes, and executive orders. In addition, Indians retain treaty-secured cultural, economic, and hunting and fishing rights within lands ceded to the United States. Indian Reservation lands are held in trust by the United States, with the Secretary of the Interior having the principal responsibility for maintaining that trust. Each reservation is governed by a sovereign tribal government. Tribal governments have among their many sovereign powers the right to regulate the uses of land and resources within their reservation boundaries, including the use and management of fisheries and wildlife resources and habitat.

Indian people revere all lands, forests, and wildlife. They have managed their lands prudently for centuries. They recognize the environmental, cultural, and spiritual values of those lands, as well as the economic values and the importance of appropriate forestland management to wildlife. They have taken and will continue to take measures to protect reservation wildlife populations, including the spotted owl. Given this historical perspective, the Tribes are voluntarily managing portions of their reservation trust lands in a manner consistent with the northern spotted owl recovery effort. These voluntary contributions are made because the protection of all species — including spotted owls — is ingrained in Indian culture.

Within the range of the northern spotted owl, there are six Indian reservations that contain northern spotted owl activity centers: the Yakima Indian Reservation, located in the eastern Washington Cascades province; the Quinault Indian Reservation, located in the Washington's Olympic Peninsula province; the Warm Springs Indian Reservation, located in the eastern Oregon Cascades province; the Grand Ronde Indian Reservation, located in the Oregon Coast province; the Hoopa Valley Indian Reservation, located in the Klamath province of California and the Round Valley Indian Reservation located in the California Coast province. The following accounts of contributions to owl recovery were provided by the respective Tribes.

Yakima Indian Reservation, Washington

Timber harvests on the Yakima Indian Reservation are done almost exclusively under uneven-aged management prescriptions. This reduces impacts to suitable owl habitat while allowing harvesting to proceed. The reservation contains approximately 500,000 acres of forested habitat, of which about 50 percent (250,000 acres) currently is classified as suitable owl habitat. Typically, the northern spotted owl habitat on the Yakima Indian Reservation lies within a band approximately 30 miles (north to south) by 25 miles wide. This band starts near the Cascade crest at elevations below 5,000 feet and extends east until it reaches pure ponderosa pine timber stands. Within that habitat there is an existing block of 60,000 acres of prime suitable habitat that is in Tribally designated reserve status. To date only about 25 percent of the total suitable habitat and less than 5 percent of the reserved area habitat have been surveyed for owls. Twenty-four activity centers have been located during 1989-1991 owl surveys. At a minimum the tribal biologists estimate a total of at least 50 nesting sites will be found when surveys of all owl habitat have been completed.

The Yakima Indian Nation has a large, effective, fisheries and wildlife staff that reviews all on-reservation activities that may have environmental impacts.

Currently, the Yakima Indian Nation employs 14 full-time biologists and wildlife technicians on northern spotted owl inventory, monitoring, and habitat utilization studies. Data from these studies will yield valuable insights into the compatibility of uneven-aged forest management techniques in maintaining spotted owl habitat suitability.

Quinault Indian Reservation, Washington

Under the Indian Allotment Act the 208,000-acre reservation was allotted to individual Indians in 40- and 80-acre parcels. In order to obtain quick cash many of the allottees either obtained fee patents and sold the land to non-Indian timber interests or demanded that their timber be harvested at an accelerated rate. By 1987 the Quinault Indian Nation owned less than 15,000 acres of its 208,000-acre reservation. By 1991 this ownership had increased to nearly 54,000 acres. The Nation's aggressive reacquisition of its reservation was enhanced by the passage of Public Law 100-638. This law returned a portion of the northern boundary of the reservation to the Nation because of a previous survey error (12,000 acres of actual ownership and 5,400 acres along the eastern boundary of the reservation in which 45 percent of the revenues are pledged to the Nation). A prime stipulation in P.L. 100-638 was that revenues generated from the harvest of timber from the north boundary area must be used by the Nation for consolidating land ownership within the Quinault Reservation. This Act is proving to be very successful and will enable the Nation, in the long term, to better manage wildlife and fisheries throughout the reservation.

Spotted owl surveys have been completed on all suitable habitat within the reservation. Only one activity center has been located. This center is in the north boundary area. Harvest within this area will be adjusted to protect this activity center core as long as it remains occupied. This activity center is adjacent to the Olympic National Park, which provides the majority of suitable habitat in the area.

It should be noted that the Quinault River valley (approximately 50 square miles on the reservation) and the river's many tributaries form the most important reservation resource to the Quinault people. Preservation and conservation of five species of salmon, two species of trout, and others always will be a main Quinault objective. All other wildlife in this area also are considered in the management scheme. Because the Quinault Reservation originally was allotted to individual Indians in 40- and 80-acre parcels, management of the area as a single unit historically has been difficult. To protect this resource, the Quinault Nation has placed a high priority on consolidation of the river valley into Tribal ownership through land purchase. With consolidated ownership, the Tribe will effect a more consistent and improved riparian zone management. The valley will continue to offer wildlife and fish protection as the primary management objective.

Warm Springs Indian Reservation, Oregon

Currently, 40 percent of the habitat suitable for northern spotted owls has been surveyed on the Warm Springs Indian Reservation. Seventeen activity centers have been located, primarily in the northwest portion of the Reservation.

The Confederated Tribes of Warm Springs voluntarily have acknowledged the designation of 18,722 acres to be managed for owls as a "Warm Springs Special Habitat Preservation Area" in the southern end of the Reservation.

This area is a portion of one of several larger Tribal conditional use areas, which are limited-entry set-asides. The primary function of this area is to serve as a connecting corridor and habitat expansion between two designated conservation areas (DCAs) on the Deschutes National Forest.

On a short-term basis, other suitable owl habitat will be managed to maintain some owl activity centers primarily centered on and around the 60,549 acres of Tribal conditional use areas, including the area discussed above. Additional restricted land use occurs on riparian zone "A" lands, which consist of 21,086 acres where timber harvest is not allowed and two extensive management zones; one zone contains 7,224 acres where timber harvest is not allowed, and a second zone contains 7,418 acres of 200+-year extended age harvest rotation under uneven-aged management prescriptions. All these set-aside or special management areas contain suitable owl habitat. All these special management areas consist of 96,277 acres of forested land or 25 percent of the Confederated Tribes' total forest resource.

On a long-term basis, the Tribes will mesh owl protection into their overall wildlife management plan in such a manner as to contain all the necessities of owl survival.

Grand Ronde Indian Reservation, Oregon

The entire reservation has been surveyed and only small amounts of suitable northern spotted owl habitat exists. All of this suitable habitat is in second-growth stands with the majority of the area located on the eastern part of the Reservation in the Coast Creek drainage. The Coast Creek drainage has been occupied by a successfully breeding owl pair since 1974. An additional resident bird may reside on the western part of the Reservation. Spring 1992 calling will determine if the bird found this year is a resident bird. Much of the surrounding Forest Service and BLM timber stands in the Coast Creek area are now or are approaching suitable habitat conditions for northern spotted owls.

The enabling legislation establishing the Grand Ronde Indian Reservation has as its principal purpose to provide economic and cultural stability for the restored Grand Ronde Tribe. One of the terms of the Grand Ronde Reservation Act provides that, beginning September 1988 and for the following 20 years, 30 percent of all timber revenue is to be set aside for economic development primarily in Yamhill, Polk, and Tillamook Counties. Given the above situations, the Tribe and U.S. Bureau of Indian Affairs have conducted on-the-ground surveys with the FWS to explore alternatives that will provide protection for northern spotted owls and allow a metered harvest of timber from the Coast Creek area. This agreed upon action was begun in 1991, and will continue as long as necessary.

Hoopa (Hupa) Valley Indian Reservation, California

Owl surveys have located 27 activity centers within the reservation. Voluntary consultation (meeting section 7 requirements) with the FWS has been and will continue to be completed prior to timber harvests.

Approximately 6,000 acres of the total 88,000 acres of the reservation are inherently unsuitable for northern spotted owls (natural prairies, urban areas, water bodies, etc.). Of the remaining 82,000 acres, approximately 39 percent is designated as reserves, cultural sites, stream zones or as the Hoopa Valley Wild and Scenic River view shed (Valley View Shed) along the Trinity River,

where timber harvest is limited to partial cutting. The Valley View Shed is approximately 2 miles wide (17,000 acres) and serves specifically as a view shed to the Trinity River but also effectively serves to connect DCAs on Forest Service land north and south of the reservation.

The principal protection provided to wildlife and fish species on the reservation is the maintenance of stream protection zones which are up to 400 feet wide. Stream protection zones include 4,700 acres. The Tribe is concerned with the protection of threatened and endangered species of fish; wildlife and plants; and also culturally important species such as, chinook and coho stocks, lampreys, fishers, pileated woodpeckers, acorn woodpeckers, bald eagles, ospreys, Port Orford cedars, and others.

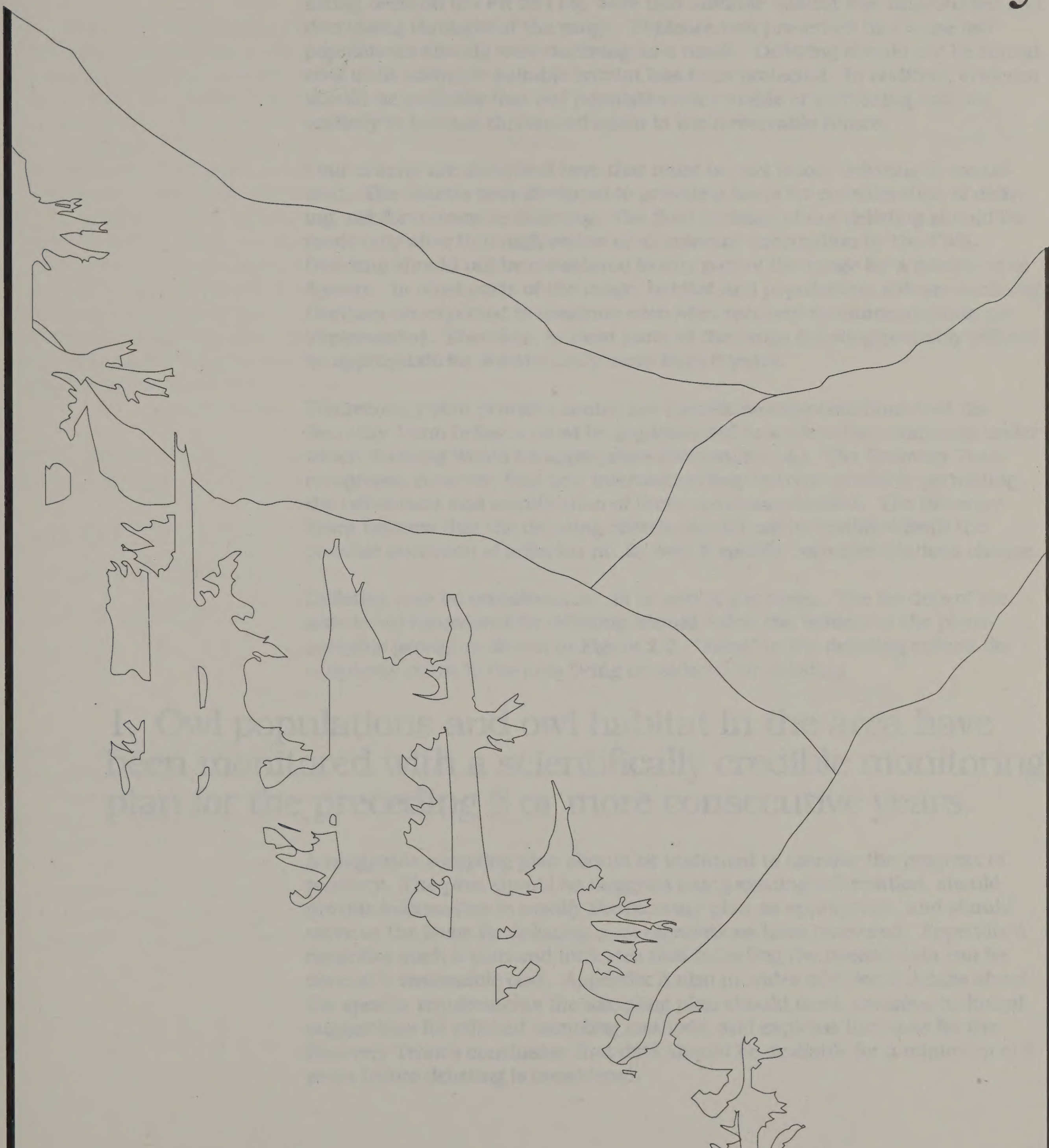
Round Valley Indian Reservation (Covelo Indian Community), California

A wildlife management survey has been initiated to survey all wildlife species on the Round Valley Indian Reservation. A spotted owl survey was conducted in the 1991 season. Within the 30,000-acre reservation a survey was conducted on land recently purchased —11,304 acres purchased with a timber cutting right easement where conifers more than 11 inches in diameter remain the property of the prior landowner. This resource area had one spotted owl activity center. If harvest is not undertaken under the easement and after a complete survey of the reservation has been done, the Tribe will reevaluate its management to provide protection for this activity center.

The Tribe has a new Fish and Wildlife Program that works in conjunction with the Natural Resource Program to manage and protect its wildlife resources within the reservation. For now, the Tribe will manage for the northern spotted owl and continue to inventory this species habitat and will develop its own management plan.

Chapter III

Recovery



III.

A. Recovery Objective and Delisting Criteria

The objective of the recovery plan is delisting of the northern spotted owl throughout its range. The major threats to the subspecies, identified in the listing decision (55 FR 26114), were that suitable habitat was unprotected and decreasing throughout the range. Evidence was presented that some owl populations already were declining as a result. Delisting should not be considered until adequate suitable habitat has been protected. In addition, evidence should be available that owl populations are stable or increasing and are unlikely to become threatened again in the foreseeable future.

Four criteria are described here that must be met before delisting is considered. The criteria were designed to provide a basis for consideration of delisting, not for automatic delisting. The final decision about delisting should be made only after thorough review of all relevant information by the FWS. Delisting should not be considered in any part of the range for a minimum of 8 years. In most parts of the range, habitat and populations still are declining. Declines are expected to continue even after recovery recommendations are implemented. Therefore, in most parts of the range delisting probably will not be appropriate for substantially more than 8 years.

The recovery plan provides numerous specific recommendations that the Recovery Team believes must be implemented to achieve the conditions under which delisting would be appropriate (section III.C.4.). The Recovery Team recognizes, however, that new information may become available permitting the refinement and modification of these recommendations. The Recovery Team believes that the delisting criteria should not be modified (with the possible exception of criterion no. 2) even if specific recommendations change.

Delisting may be considered for all or part of the range. The borders of the area being considered for delisting should follow the borders of the physiographic provinces shown in Figure 2.2. "Area," in the delisting criteria descriptions refers to the area being considered for delisting.

1. Owl populations and owl habitat in the area have been monitored with a scientifically credible monitoring plan for the preceding 8 or more consecutive years.

A rangewide sampling plan should be instituted to monitor the progress of recovery. The plan should be designed using existing information, should provide information to modify the recovery plan as appropriate, and should serve as the basis for delisting once populations have recovered. Appendix A describes such a plan and indicates that collecting the needed data can be done at a reasonable cost. Appendix A also provides additional details about the specific requirements the sampling plan should meet, contains technical suggestions for efficient sampling methods, and explains the basis for the Recovery Team's conclusion that data should be available for a minimum of 8 years before delisting is considered.

2. The population has been stable or increasing during at least the last 8 years, as indicated by both density estimates and demographic analyses, in all parts of the area that would be considered significant under the Endangered Species Act.

Delisting a threatened population while it is declining would be difficult to justify. This is particularly true with northern spotted owls because evidence that populations were declining was one of the major reasons for listing the subspecies. These statements apply to the total population in the area being considered for delisting, or to any subpopulation that would be considered "significant," and thus would qualify for protection under the Endangered Species Act. The Recovery Team recognizes, however, that suitable habitat in the matrix—and owl populations—are likely to decline, and several decades may be required before populations stabilize completely, even if recovery is proceeding as anticipated. The Recovery Team believes that delisting eventually might be appropriate if the populations in protected areas were stable or increasing, even if the overall population still was declining slightly. The criteria for delisting under these conditions are difficult to specify precisely at this time, and doing so may be unnecessary if habitat protection in the matrix is integrated successfully with other forest activities (section III.B.2.). For these reasons, the Recovery Team has not attempted to specify the exact criteria for delisting while the population still is declining at a small rate.

State-of-the-art methods should be used to estimate population trends. Methods that would be appropriate at present are described in Appendices A and C.

3. Regulatory mechanisms or land management commitments have been implemented that provide for adequate long-term protection of breeding, foraging, and dispersal habitat, as described in section III.C.4., recovery goals and strategies for each province.

Delisting would be followed by loss of protection under the Endangered Species Act. Adequate protection through alternate means is essential before delisting. For example, management plans for federal land should provide adequate assurances of habitat protection prior to consideration of delisting. The form of these regulations and commitments should be determined during the coming years and will vary across the range. The Recovery Team therefore has not attempted to specify the form of the protection precisely. Reasonable assurance must exist that the conditions which have brought about population stability will be maintained, or, if necessary, improved during the foreseeable future.

4. The population is unlikely to need protection under the Endangered Species Act during the foreseeable future.

Populations that are temporarily stable but likely to decline again in the foreseeable future cannot be considered recovered and should not be delisted. Detailed analyses of the likelihood that the population will remain stable or increase must be carried out before delisting. The analyses should include observed and anticipated effects of a) fluctuations in abundance, fecundity, and survivorship; b) movements by birds within the area and to or from surrounding areas; c) changes in habitat including ones due to catastrophic events; d) loss of genetic diversity; and e) any other threats to the population whose effects might be significant. These analyses are particularly important for small populations.

III.

B. Principles Followed in Developing the Plan

1. Strategic Principles

Adequate assurance of recovery must be provided.

Secretary Lujan's letter directed the Recovery Team to prepare a plan which would "bring the owl to the point at which it will no longer need the protection of the Endangered Species Act." The directive to the Recovery Team recognized the "biological imperative" in the Endangered Species Act. No plan would be acceptable unless it provided adequate assurance that recovery would be achieved. Proposals for recovery were evaluated first to determine whether they provided adequate assurance of recovery. This evaluation was made without regard to economic implications of the proposal, and all proposals were required to meet this biological imperative prior to being given further consideration.

The plan should minimize social and economic costs.

The Recovery Team attempted to develop a plan which, while meeting the requirement of achieving recovery, would recognize and try to reduce the overall cost and would distribute this cost in an equitable manner across the region. For example, the Recovery Team made an intensive effort to place DCAs in locations where timber yield already was reduced (e.g., national parks, wilderness areas); efforts were made to distribute DCAs in a way that reduced adverse effects on timber-dependent communities; and analyses were carried out to identify activities within DCAs that might produce economic returns without reducing the assurance that recovery would occur.

The plan should be comprehensive.

Secretary Lujan directed the Recovery Team to develop a plan that "will serve as a guide to future federal, state and private activities affecting the owl." These activities will include research, monitoring, habitat protection, development of conservation plans, and numerous other efforts to bring about recovery. The Recovery Team attempted to integrate all of these activities into a single, well-coordinated plan for achieving recovery using all tools available under the Endangered Species Act.

All contributions to recovery should be recognized.

Important contributions to recovery are being made on nonfederal land and on federal land outside of DCAs. Some of these contributions are required for recovery, but others may provide higher levels of protection than are needed to assure recovery. These measures should not be required, and if they are contributed voluntarily, then the possibility of requiring less contribution from other sources should be investigated. This approach is consistent with the goal of minimizing the cost of recovery, and may be particularly important as an incentive for nonfederal landowners to find owls and develop long-term conservation programs for them.

Needs of other species should be considered.

Secretary Lujan directed the Recovery Team to consider "effects on other threatened and endangered species and those species which might be listed in the future." The Recovery Team attempted to identify these species and the requirements of a select group of priority species. Efforts then were made to ensure that the recovery plan provided this protection to the maximum extent practical without increasing the overall cost. The plan also contains additional information on the status of these species. The Recovery Team believes that landowners and managers may want to consider these other species in an effort to reduce the long-term costs of protecting species in these ecosystems.

The plan should be responsive to new information.

As new information is produced by the monitoring and research program, more efficient ways to bring about recovery may be developed. New data may indicate that DCAs need to be larger or smaller; modification of the monitoring program may be required; improved silvicultural methods may be demonstrated to create and maintain owl habitat, or for integrating timber production with owl protection; and new, more effective administrative procedures may be devised. The Recovery Team wants to encourage the development and implementation of these improvements. Specific recommendations are included for revising the plan periodically and for assuring that proposed modifications to the plan are considered fully and implemented as appropriate.

2. Biological Principles

This recovery plan is based on biological principles that are accepted widely by conservation biologists. The application of these principles to northern spotted owls first was described in the Conservation Strategy of the Interagency Scientific Committee (Thomas et al. 1990). The most important of these principles are that 1) species are more secure from extinction if habitat and local populations are distributed across their entire range; 2) providing for species in large habitat blocks is superior to providing small blocks; and 3) movement of individuals throughout the landscape is vital to the maintenance of all local populations within the range. A summary of the reasons behind each of these principles and their application to northern spotted owls follows.

The risk of local or widespread extirpation of northern spotted owls will be reduced by managing for owls across their entire range and the variety of ecological conditions within that range.

Four primary reasons can be cited for the importance of maintaining the full range of the species. First, any significant range reduction most likely would reduce the total number of local populations in the species' metapopulation. The security of the metapopulation is related directly to the number of local populations. A reduction in local populations increases the risk of extinction for the whole metapopulation. Second, a reduction in range also would reduce the overall range of environments occupied by the species, making the species more vulnerable to environmental stochasticity. Habitats at different elevations, in different forest types, in different ownerships, and in different parts of the owl's geographic range may act as refugia for the species in the face of catastrophes, rapid environmental change, chronic degradation of habitat from causes such as forest diseases, or unforseen changes in interactions among species. Populations distributed across the geographic and ecological conditions within the range provide a higher likelihood that the subspecies will survive such events.

For these two reasons, Thomas et al. (1990) concluded that species well-distributed across their range are less prone to extinction than species confined to smaller portions of their range. Third, range reduction around the fringes of a species' geographic or elevational range could have serious consequences because these areas are often the sites of the most rapid adaptations within a species. Eliminating the fringes of the range might reduce the evolutionary capability of the species. Fourth, the elimination of the geographic or elevational fringe portions of a species' range might be considered unwise in the face of possible widespread climatic changes, especially where the direction and magnitude of those changes are uncertain. For example, some scientists believe that global warming could result in some local cooling points in the Pacific Northwest rather than a universal warming effect (Smith 1990). If the climate cooled, it could place increasing importance on the southern parts of the range and on low elevation habitats. If the climate warmed, it could place increasing importance on the northern extent of the range.

Emphasis should be placed on management for clusters, or local population centers, of owls in large habitat blocks rather than for individual pairs.

Empirical evidence and modeling show that clusters of 15 to 20 breeding pairs have much higher persistence rates than small, isolated clusters. These clusters, or local population centers, can be defined as groups of breeding owls where pairs have overlapping or nearly overlapping territories. The evidence and rationale supporting this principle are described in detail in Thomas et al. (1990).

One of the advantages of local population clusters is that they can provide for a population structure that can sustain itself for many generations. This contrasts with extremely small local populations, composed of two or fewer pairs, that are highly susceptible to local extinction (Diamond 1984). In order to realize this advantage, the local populations must be large enough to hold multiple breeding pairs, and also support juveniles, subadults, and "floaters." Floaters are nonbreeding individuals without established territories. It is thought that they serve as ready replacements for birds that die or vacate their territories for other reasons (Thomas et al. 1990). This ready replacement of birds in breeding territories should help maintain the populations within the local population centers.

Within each local population center, it is critical to provide for stable or improving habitat conditions. This will reverse the trend of increasing fragmentation of habitat which has been experienced in most areas across the range. Fragmentation of habitat is associated with lowered spotted owl densities, decreased productivity of spotted owl populations (Bart and Forsman 1992), increasing susceptibility of forest stands to windthrow, decreasing success of juvenile dispersal, and possibly increased competition with barred owls and predation by great horned owls (Thomas et al. 1990).

For a strategy based on local populations to be successful, those local populations must be capable of acting as sources of surplus owls for the species' metapopulation. A source area is one that has a positive rate of population increase and is capable of contributing individuals to the metapopulation. Local populations might cease to act as sources if they are too small or if they occupy highly fragmented habitat (Thomas et al. 1990). It is important to note that each local population does not have to act as a source each year. It is expected that there will be some variation across populations and across years, and that a portion of the local populations would not act as sources in some

years. The strategy of managing for many local populations within the metapopulation should allow maintenance of a nondeclining trend in the metapopulation despite this variation.

The management for local populations within the metapopulation also should be designed to reduce the risk of local or widespread extirpation of owl populations due to catastrophic destruction of habitat. Such destruction could result from natural causes including windthrow, fire, flooding, insects, diseases, volcanic action, or climatic change. The risk to the overall population from large-scale disturbances is reduced by distributing local population centers across the species' range, and by providing redundancy of habitats. Additional security from catastrophic loss can be provided by reducing the risk within local population centers. The risk of catastrophic loss within a given population center can be influenced by the size, configuration, and management of that center. Larger areas are less susceptible to complete elimination from fire and windthrow. The likelihood of fire, and the likely impacts of fire, can be reduced through management of fuels both within the population center and in the surrounding forest matrix. In some ecological conditions, the risk of serious insect and disease losses may be reduced through appropriate management.

Habitat conditions and spacing between local populations must provide for survival and movement of northern spotted owls.

Metapopulations are sets of local populations that are linked by dispersing individuals. While each local population might be subject to extirpation over the long term, individuals dispersing among the areas help to reestablish local populations after severe local declines or extirpations. The interbreeding provided by dispersing individuals also provides insurance against deleterious effects of inbreeding. To allow for movement of northern spotted owls among source areas, those areas must be spaced appropriately; there must be redundant linkages among areas; and the intervening habitat must provide the dispersal needs of adults and juveniles.

Studies of dispersing juvenile owls (Miller 1989, Gutiérrez et al. 1985) indicate that their initial movements have a strong random component. The probability of a juvenile finding suitable habitat is related to the amount of suitable habitat in the landscape around its natal area and the distance of that habitat from its starting point. Increasing the number of blocks of suitable habitat within the dispersal distance of any given local population center will increase the chance for success of dispersing juveniles. Also, having each block within the dispersal distance of two or more other blocks allows the system of local population centers to retain connectivity even if a given local population is eliminated. In this case, that population center can be reoccupied by owls coming from two or more other centers.

The connecting zones among local population centers must contain habitat that will allow movement of juvenile and adult dispersers and provide for basic life needs during the dispersal period. Key elements for survival include roosting opportunities, protection from predators, and adequate foraging opportunities (Thomas et al. 1990).

3. Integration of Strategic and Biological Principles

The northern spotted owl has been placed at risk by management actions that have seriously depleted its habitat. The habitat conditions that would be best for support of an owl population would be similar to those that existed before timber harvesting began. However, recreating such habitat conditions would not be feasible. Efforts to restore habitat conditions in any part of the range would have large economic effects, and those economic consequences force difficult biological choices in the design of a recovery strategy. The strategy developed here places large blocks of habitat on federal land off-limits to regular timber harvesting and should provide a reasonable assurance of success of recovering the northern spotted owl. However, it required consideration of many compromises in conservation area size and spacing and the structure of intervening forests. Such compromises are inevitable in a strategy that calls for blocks of superior habitat distributed within a landscape of lower quality habitat. The situation for owls could be made more secure if favorable habitat conditions could be spread more evenly across the landscape. Such a solution might be possible if it can be demonstrated that silvicultural techniques can create and maintain suitable habitat conditions while harvesting timber. The Recovery Team supports the change over time toward such a solution when supported by appropriate data.

III.

C. The Recovery Plan

1. Overview

The recovery plan strategy is based on the principles stated in section III.B. The plan has three main components: establishing designated conservation areas (DCAs) on federal lands; managing the remaining federal land, referred to as the matrix; and encouraging contributions from nonfederal lands.

Federal Lands

The network of DCAs follows guidelines developed by Thomas et al. (1990). The DCAs provide for local population centers, or clusters, of reproductive pairs. It is anticipated that birth and survival rates in these clusters normally will equal or exceed death rates, allowing the clusters to serve as source areas for owls. The clusters are arranged across the federal landscape to meet, as nearly as possible, the principle that northern spotted owls should be recovered across their entire range and the full variety of ecological conditions within that range.

DCAs will be managed to improve owl habitat. Thinning and other silvicultural practices will be used to accelerate development of suitable habitat in areas that are currently unsuitable. Such management, however, will be used only where existing and new studies and data indicate that the development of suitable conditions could be accelerated. Salvage of dead trees in stands affected by large-scale disturbances also may take place, but only where that salvage will have a positive or neutral effect on owl habitat. Additional management activities are recommended in DCAs where there is significant risk of large-scale habitat destruction by fire, wind, insects, or disease. Detailed guidelines for management in DCAs are in section III.C.2.

Outside the DCAs, it is recommended that federal forestlands be managed to allow dispersal of owls among DCAs. These forests are called the matrix, following the terminology established by Thomas et al. (1990). Dispersal of owls among DCAs is important to replace owls that die and to avoid loss of genetic diversity. This is important under normal circumstances, when individual owls die, and unusual circumstances, when there is large-scale disruption of the population.

Federal matrix lands also will provide habitat to supplement DCAs in areas where existing conditions preclude achievement of the goals for size and spacing of DCAs. These areas of additional habitat are called reserved pair areas. Specific criteria were used to determine where they should be delineated (section III.C.2.).

In the eastern Washington Cascades, large-scale habitat disturbances are likely, due to fire and insect outbreaks. These disturbances are a significant threat to the sparse spotted owl population in that area. To reduce the risk, the plan recommends providing habitat for additional owl pairs and territorial single owls outside of DCAs. The plan also recommends managing these areas to reduce risk of fire and insect damage.

Finally, the plan recommends maintaining residual habitat areas around existing owl pairs and territorial singles. These small areas will help maintain options to provide for owls throughout the landscape in the future.

A broader array of management practices will be used in the matrix than in the DCAs. The timing and location of management practices will be designed to achieve desired conditions through time. Details of matrix management are in section III.C.2.

Nonfederal Lands

In many areas throughout the owl's range, federal lands are not adequate to provide recovery. In these areas, nonfederal actions are needed. Currently, primary nonfederal action is providing habitat for existing owl pairs to avoid take of those owls as defined by the Endangered Species Act. A variety of nonfederal contributions is envisioned in this plan (section III.C.4), and many contributions may be made in lieu of take provisions. These actions are termed protective management and may include: 1) helping to meet objectives for DCAs where nonfederal lands are mixed with federal lands; 2) providing for clusters of breeding pairs on nonfederal lands; 3) providing habitat for individual owl pairs; and 4) providing dispersal habitat.

Evolution of the Strategy

The recovery strategy should evolve as more information is collected on owls and their habitat. The monitoring and research program is designed to provide that information. The recovery plan recommends establishing an interagency group to coordinate this gradual refinement and modification of the recovery plan strategy, and it recommends maintaining the Recovery Team to fulfill this function until such a group is established.

Organization of This Chapter

All facets of the proposed recovery plan are discussed in the following sections. Section III.C.2. reviews management on federal lands. It discusses the delineation of DCAs; criteria used to determine where matrix prescriptions should be applied; and specific management recommendations for the DCAs and the matrix. Section III.C.3. discusses implementation strategies and tools for federal and nonfederal lands, and a proposed implementation schedule. Section III.C.4. presents a comprehensive discussion of recovery goals for all lands in each physiographic province. It also describes how those goals might be implemented on nonfederal lands. Section III.C.5. describes coordination efforts that will be needed to make the recovery plan successful. Section III.C.6. outlines the monitoring and research program that will be needed to improve the plan over time and to provide information for delisting.

2. Management Guidelines for Federal Lands

Designated Conservation Areas

Delineation of DCAs

The DCAs recommended on federal lands in this plan were derived from the habitat conservation areas (HCAs) proposed by Thomas et al. (1990). The objective of the original HCA network was to establish habitat areas large enough to support 20 pairs of owls with contiguous or nearly contiguous home ranges. The 20-pair goal was based on empirical evidence and on simulation modeling which showed that clusters of 20 interacting pairs were likely to persist for at least 100 years. These areas were to be spaced a maximum of 12 miles apart, edge-to-edge. The spacing guideline was developed to ensure that juvenile owls, dispersing from their birthplace, would be able to find suitable habitat for nesting. Two-thirds of the juvenile owls studied at the time of the ISC report had moved at least 12 miles. HCAs were as circular as possible to minimize the perimeter-to-area ratio.

The 20-pair HCAs were termed category 1 HCAs. Where 20-pair areas could not be established, Thomas et al. (1990) recommended smaller areas capable of supporting two to 19 pairs. These smaller areas were termed category 2 HCAs. The draft recovery plan adopts this convention for category 1 and category 2 DCAs. However, some of the category 2 DCAs have the capability of supporting only a single pair of owls.

Thomas et al. (1990) used median annual home range size and density information to determine the appropriate size for the category 1 HCAs. HCAs were delineated to include the best available habitat and greatest number of known pairs or territorial singles. This process was done iteratively to achieve the best combination of habitat, known owls, and HCA shape. Where category 2 HCAs were delineated because there was no opportunity to create category 1 HCAs, these smaller areas were spaced at a maximum distance of 7 miles. Approximately 80 percent of juveniles that have been studied with radio transmitters have traveled at least this far (Thomas et al. 1990).

The HCA network was modified slightly in the draft recovery plan using updated inventories of owls and habitat (see Appendix I). Size and spacing criteria were not changed. Boundaries were altered to improve the biological and/or economic efficiency of the system. The resulting DCAs are summarized in Tables J.1 through J.11 in Appendix J.

There were 196 DCAs identified for the DCA network, with 56 satisfying the criteria for category 1 status. The remaining 140 areas are category 2 DCAs. To determine which DCAs met the criteria for category 1 status, the future capability of a DCA to support owl pairs on federal lands in the DCA was calculated. This figure was determined by assuming that 80 percent of the land within the DCA would become suitable owl habitat over time. The actual calculation is explained in Appendix J. In a few cases, where federal lands could support more than 15 pairs but not 20 pairs, the presence of existing owl pairs on nonfederal lands provided the basis for accepting DCAs as category 1.

A total of 1,181 pairs of owls has been located on federal lands in these DCAs within the last 5 years. This represents 48 percent of the 2,460 pairs of owls located on all federal lands during that period. The percent of owls included in DCAs by state is 81 percent in Washington, 39 percent in Oregon, and 54 percent in California. Differing percentages among the states result from the differences in current population levels and distribution of owls. The DCAs contain approximately 7.5 million acres of federal land including approximately 3.5 million acres of nesting, roosting, and foraging (NRF) habitat. This represents about 48 percent of all NRF habitat on federal land. The percent of habitat included in DCAs by state is 55 percent in Washington, 44 percent in Oregon, and 43 percent in California. A summary of the DCA network is presented in Figures 3.1 and 3.6. The DCA network is illustrated on the maps included with the recovery plan, and it is discussed further in section III.C.4. Additional pairs of owls on federal lands will be protected by matrix management prescriptions. See sections III.C.2. and III.C.4.

Management of DCAs

Effective management of the DCAs is necessary to achieve recovery. This section describes the management guidelines that will govern activities on federal lands in DCAs. These guidelines apply to the owl's entire range. They must be refined and use province-specific information before they can be applied to projects. It is recommended that interagency groups be established to develop this province-specific guidance. Implementation of the guidelines will be accomplished by preparing management plans for individual DCAs. The recommended components for DCA management plans are described briefly in this section and in more detail in Appendix E.

The DCA management guidelines have several key objectives. First, they allow natural successional processes to continue operating in areas of currently suitable habitat. They focus silvicultural activities within DCAs on developing suitable habitat conditions for owls where those conditions now do not exist. Another objective is to maintain or reestablish suitable conditions in areas being considered for salvage operations. Finally, maintaining currently suitable habitat conditions is an important consideration in areas where there is significant threat of large-scale disturbances (i.e., mixed conifer forests in the eastern Cascades). Some forest management activities which meet these objectives also may yield commercial wood products, but such products should not be part of the programmed timber harvest. In addition, the DCA management planning process will allow other ongoing activities to continue within DCAs where they are compatible with owl recovery.

The recovery plan recommends the preparation and approval of a management plan for each DCA before design and implementation of habitat manipulation activities. Land management agencies may choose to develop these plans as components of legally mandated plans (e.g., forest or resource management plans), or as stand-alone plans. Agencies are strongly encouraged to develop province-based planning guidelines as a basis for preparing plans. DCA management plans will serve as overview documents that provide a framework for carrying out specific activities. Individual plans should include: 1) a history and inventory of overall owl and habitat condition; 2) a description of other resources and land uses; and 3) criteria for determining appropriate treatments for specific owl needs and on-the-ground conditions within the DCA, consistent with the recommendations in this section and other applicable guidance. Individual DCA plans should contain oversight, monitoring, and evaluation components to help assure that activities are carried out as intended and achieve desired results. Interdisciplinary teams that include wildlife biologists, silviculturists, forest ecologists, fire scientists, forest ento-

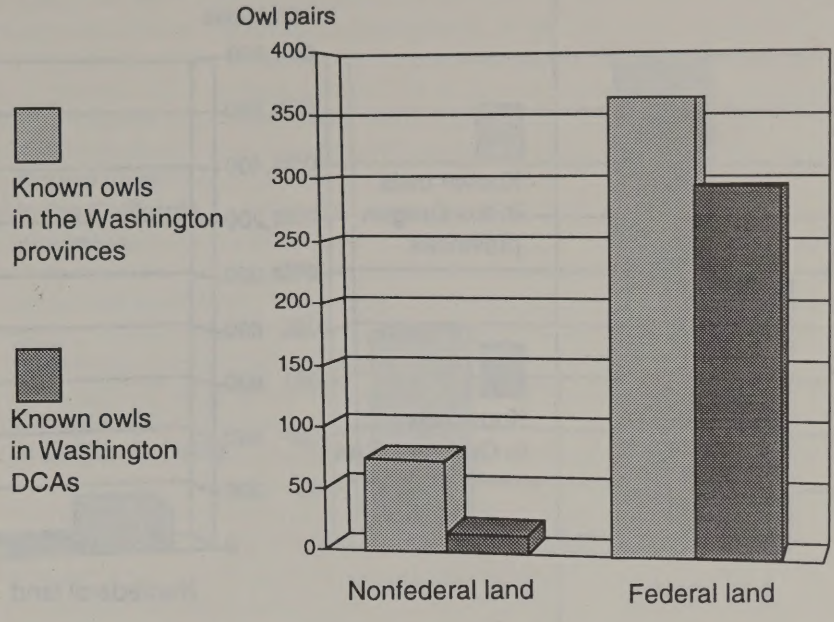


Figure 3.1. Total known owl pairs in the Washington provinces and in DCAs within the provinces.

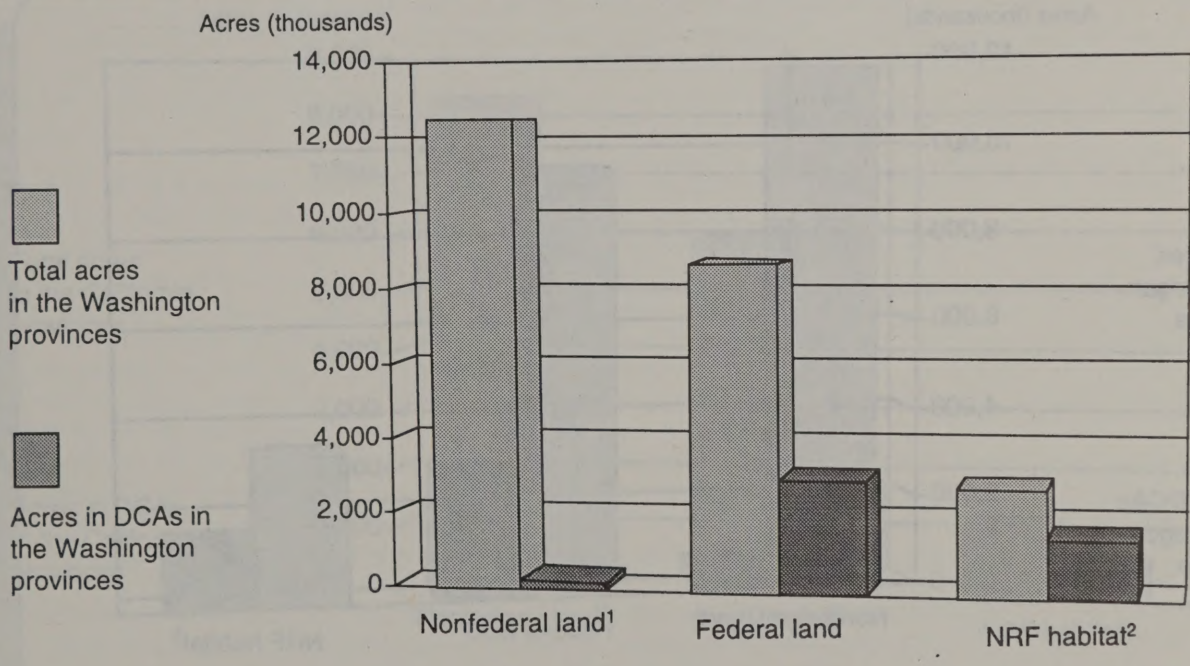


Figure 3.2. Acres in the Washington provinces and in DCAs within the provinces.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

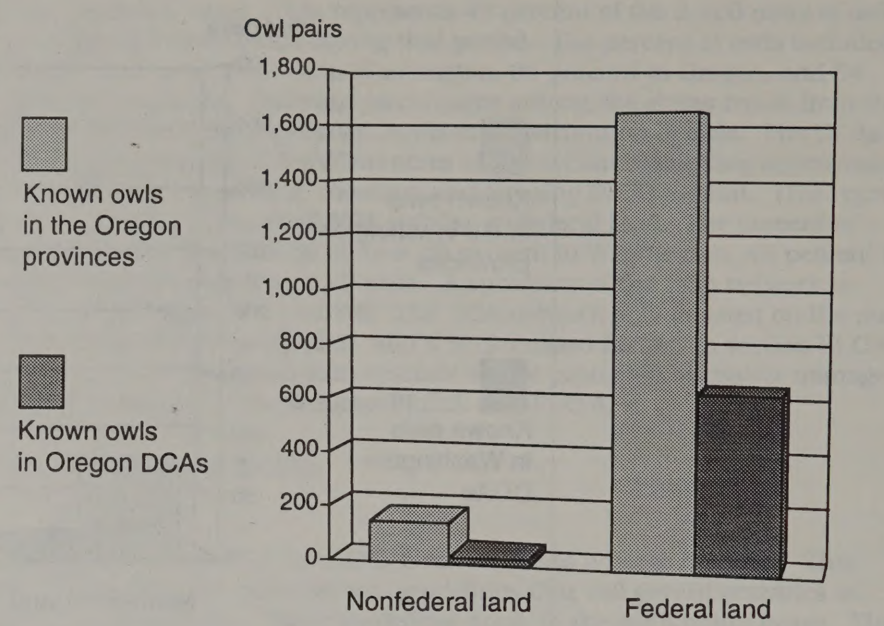


Figure 3.3. Total known owl pairs in the Oregon provinces and in DCAs within the provinces.

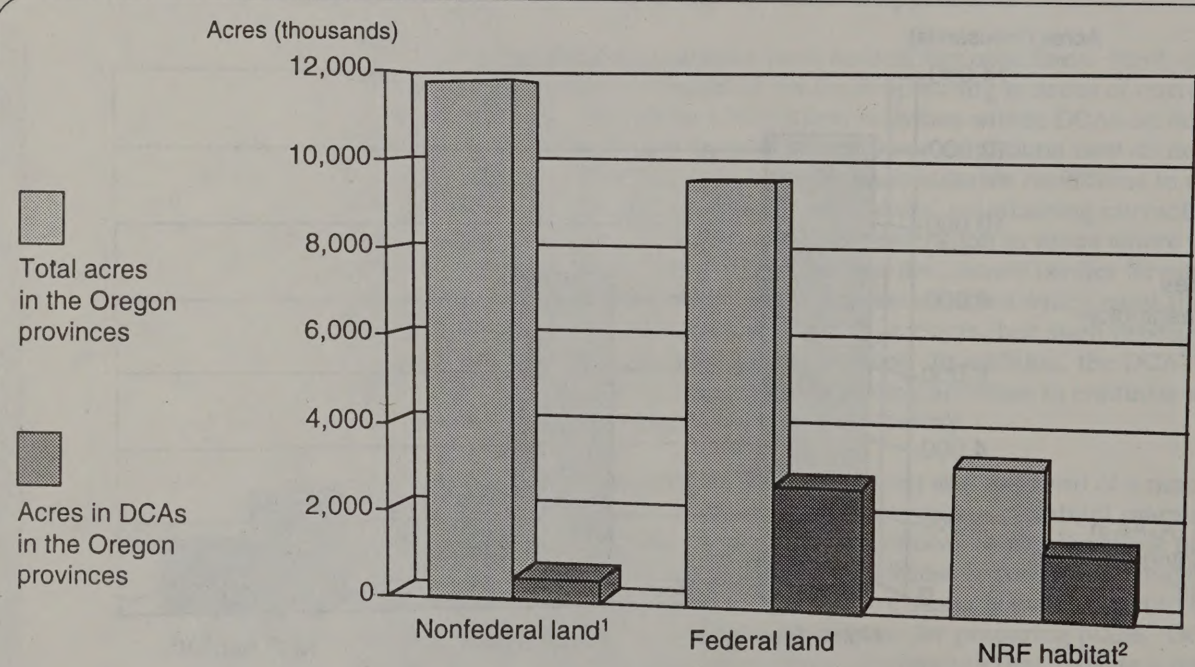


Figure 3.4. Acres in the Oregon provinces and in DCAs within the provinces.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

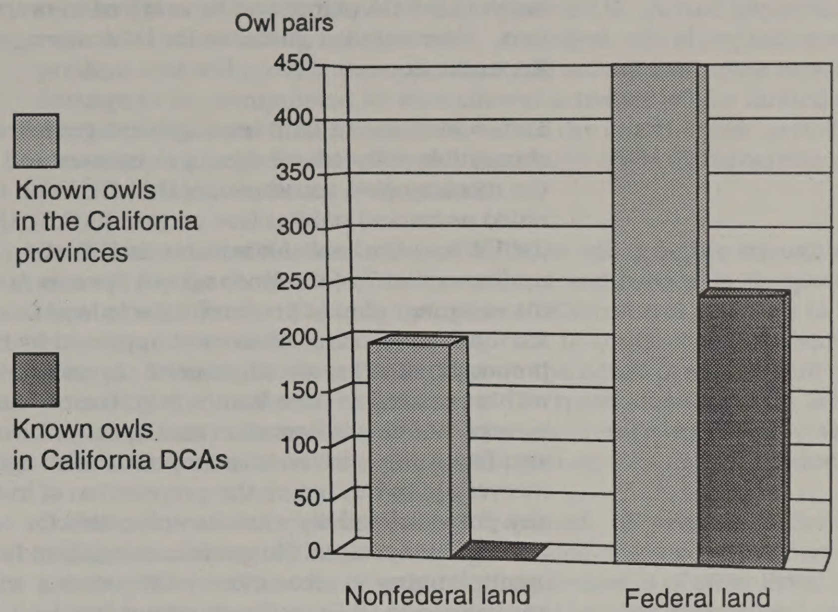


Figure 3.5. Total known owl pairs in the California provinces and in DCAs within the provinces.

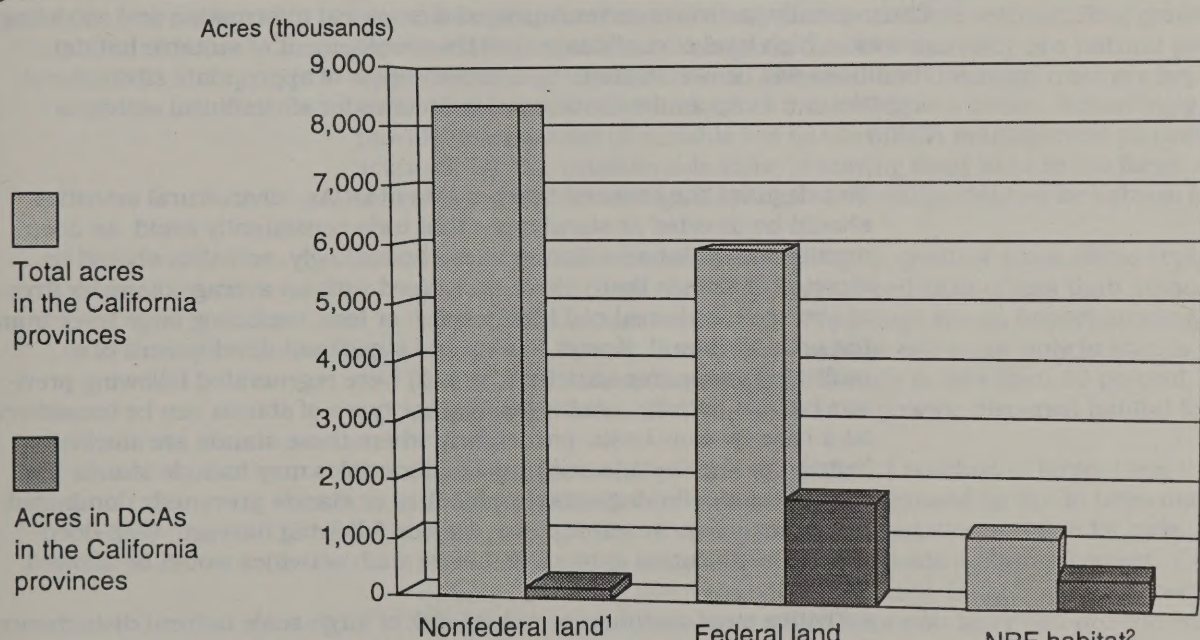


Figure 3.6. Acres in the California provinces and in DCAs within the provinces.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

mologists, and representatives of other appropriate disciplines should write the individual DCA plans, and be involved in oversight actions after implementation. More detailed guidance for DCA management plan preparation is in Appendix E.

The recommended DCA management guidelines and planning process are compatible with federal agency mandates and management frameworks. Since the recovery plan recommends that DCAs on certain federal lands be designated as critical habitat (see section III.C.3), the guidelines should be used by the FWS as the basis for adverse modification determinations for those lands under section 7 of the Endangered Species Act. Accordingly, after a DCA management plan is prepared by a federal land management agency, submitted for formal consultation, and approved by the FWS, it is expected that proposed activities would proceed. Agencies must provide for plan revisions within reasonable time frames (e.g., the normal agency planning cycle) to incorporate new information and in cases involving major disturbances (e.g., a significant fire). In the interim period after agency implementation of the recovery plan but before the preparation of individual DCA management plans, any proposed activity must be submitted for consultation on a case-by-case basis. Finally, since the guidelines apply to federal lands in DCAs, management planning in areas of mixed ownership will necessitate approaches that are tailored to the specific situations involved. For example, interagency coordination will be needed to ensure effective monitoring and to manage risks of large-scale disturbances. In addition, coordinated planning will help ensure that maximum benefit is derived from the contributions by all landowners.

Guidelines for Silviculture. The primary objective of silvicultural activities in DCAs is to improve habitat in stands with currently unsuitable conditions. Consequently, activities are encouraged if empirical information and modeling provide a high level of confidence that the development of suitable habitat conditions will be accelerated. Specific examples of appropriate silvicultural activities are in Appendix G. General guidelines for silvicultural activities follow.

1. To safeguard the conservation benefits of DCAs, silvicultural activities should be directed at stand types that owls consistently avoid, as documented in habitat selection studies. Accordingly, activities should be directed at stands that: 1) are even-sized with an average diameter (tree of average basal area) of 11 inches dbh or less, excluding large trees from the previous stand, if any; 2) show no significant development of a multiple-canopy tree structure; and 3) were regenerated following previous harvest activity. Activities in other types of stands can be considered on a case-by-case basis, particularly where those stands are stocked heavily and not being used by owls. Examples may include stands that were planted following catastrophic fires or stands previously dominated by conifers that converted to hardwoods following harvest. Well-documented justification is required before such activities would be allowed.

2. Activities must maintain or reduce risk of large-scale natural disturbance. For example, activities would not be implemented if they significantly increase the risk of windthrow in a stand.

3. To promote habitat suitability, thinning operations will leave some trees as snags and others as down wood. In addition, some trees may be removed for commercial or fuel hazard reasons.

4. Key attributes of forests inhabited by the northern spotted owl are their diversity and variability on individual sites and from site to site. To promote diversity and variability, a wide range of silvicultural practices will be applied, as opposed to reliance on a limited variety of techniques.

5. Activities that comply with these guidelines should provide positive recovery benefits as demonstrated in Appendix G. Actual implementation experience, however, is not extensive. A modest rate of implementation is prudent and will provide the opportunity to assess and refine activities. Acreage to be manipulated by silvicultural activities will be limited to 5 percent of the total area in any DCA within the initial 5-year period of the recovery plan, unless actions concerning large-scale disturbances (as described later) explicitly are justified.

6. Some habitat modification activities in DCAs will generate enough revenue to pay for themselves. Others will not and need to be supported by appropriated funds. Since the purpose of silvicultural activities in DCAs is to advance recovery, it is not appropriate to conduct only activities that generate a commercial return and ignore the needs of stands that cannot be treated commercially. A balance will be maintained between activities in young stands that produce no commercial return and in somewhat older stands that have the potential to produce commercial products.

7. Owl habitat needs increasingly are well defined. However, all species do not derive comparable benefits through actions designed to improve owl habitat. To the extent feasible, habitat requirements of other listed or candidate species also will be considered in planning silvicultural activities.

Guidelines for Salvage. "Salvage" is defined as the removal of trees from an area following a stand-replacing event which may result from wind, fire, insect infestation, or disease. In certain circumstances, salvage operations in DCAs may be compatible with recovery objectives while providing removal of merchantable wood. For example, salvage could help promote regeneration where excessive amounts of coarse woody debris interfere with seedling growth. However, it is important to recognize that tree mortality is a natural process within a forest ecosystem. Dead, diseased, and damaged trees are key components of stand structure and assist in meeting owl needs. Accordingly, to provide development of suitable owl habitat, DCA management planning must acknowledge the considerable value of leaving dead trees in the forest as well as the benefits from salvage activities. General guidelines for salvage follow.

1. The potential for benefit from salvage is greatest when stand-replacing events are involved. Salvage in disturbed sites of less than 10 acres is not appropriate because small forest openings are an important component of old-growth forests. In addition, salvage will occur only in stands in which disturbance has reduced canopy closure to less than 40 percent, as stands with more closure are likely to provide dispersal habitat for owls.

2. Surviving trees will provide a significant residual of larger trees in the developing stand. In addition, defects caused by fire in trees may accelerate development of structural characteristics suitable for owls. Also, those trees which eventually die will provide additional snags. Consequently, standing live trees will be retained, including those scorched but likely to survive. Inspection of the cambium layer can provide an indication of potential tree mortality. All trees that may live should be retained.

3. Snags provide a variety of habitat benefits for owls. Accordingly, where disturbance events leave snags, management will focus on retaining all snags likely to persist for 100 years. During this period, the stand does not otherwise contribute significant quantities of large diameter snags or down logs. Snags from the original stand may be an important component of flying squirrel habitat as forests develop after fire. Although there is some uncertainty concerning the optimum density of snags to be provided for squirrels, management to provide maximum benefit likely for

this prey species is an appropriate strategy for DCAs. Therefore, snags larger than 20-inch dbh will be retained.

This guideline may need to be refined for application in some physiographic provinces. However, retention of all stems larger than 20-inch dbh is likely to provide the highest probability of long-term retention of snags throughout the owl's range. Management planning in areas such as northern California may require specific guidance for hardwood snag retention, and to provide habitat for woodrats, a prey species. In all areas, however, the primary focus should be on long-term planning.

4. Coarse woody debris (CWD) biomass (i.e., snags and down logs) provides habitat for organisms that are important food of several owl prey species, as well as having other habitat-enhancing characteristics. In the first 100 years after a stand-replacing disturbance, the amount of CWD added by the new stand is not significant, so retaining remnant CWD from the previous stand during this time is important. Following a stand-replacing disturbance, management will provide for CWD quantities in the new stand which, after 100 years, would be similar to amounts in naturally regenerated stands at that age. As in the case of snags, province-level specifications must be provided for this guideline. Since decay rates and biomass naturally remaining at 100 years undoubtedly will vary among provinces and forest types, the specifications also will vary.

5. Some salvage that does not meet the preceding guidelines will be allowed when salvage is essential to reduce the risk of fire or insect damage to suitable owl habitat. This circumstance is most likely to occur in the eastern Oregon and eastern Washington Cascades and California Cascades provinces, and somewhat less likely in the Oregon and California Klamath provinces. It is important to understand that some risk associated with fire and insects is acceptable because they are natural forces influencing forest development where owls occur. Consequently, salvage to reduce such risks should be minimal, and considered as an exceptional practice.

6. Small-scale removal of snags and logs may be necessary to reduce hazards to humans along roads and trails and in or adjacent to campgrounds. Where materials must be removed from the site, as in a campground, a salvage sale is appropriate. In other areas, such as along roads, leaving material on site should be considered. Also, material will be left where available CWD is inadequate.

7. Where green trees, snags, and logs are present following disturbance, the above green tree and snag guidelines (discussed earlier in this section) will be applied first, and completely satisfied where possible. The biomass left in snags can be credited toward the amount of CWD biomass needed to achieve management objectives.

8. Since remnant CWD may be relatively small after disturbances in younger stands, diameter and biomass retention guidelines should be consistent with silvicultural programs designed to regenerate suitable owl habitat.

9. Logs present on the forest floor before a disturbance event provide habitat benefits which are likely to continue. It seldom will be appropriate to remove them. In addition, these logs will not be credited toward objectives for CWD retention developed after a disturbance event.

10. The CWD retained will approximate the species composition of the original stand, to help replicate preexisting suitable habitat conditions.

The following section contains an example of the application of salvage guidelines in the Douglas-fir/Western Hemlock Zone of the western Oregon and Washington Cascades. The example shows how specific guidelines would be developed for an area where an old-growth forest stand suffered catastrophic disturbance.

Applying Salvage Guidelines in Western Washington and Oregon

This example is developed for salvage of a hypothetical stand that suffered a stand-replacing fire. Prior to the fire, the stand would have been classified as old-growth. Live tree densities for the original stand are in Table 3.1

Snag Retention

Snag decomposition rates are related inversely to diameter. Equations developed by McComb and Ohmann (pers. comm.) predict that in western Washington and Oregon the probability of snags less than 20-inch dbh persisting for 100 years is near zero. Above this diameter, probabilities of snag survival increase rapidly for western hemlock and Douglas-fir.

Snags more than 20-inch dbh are especially important for cavity-nesting birds. Nelson (1989) found significant selection by cavity-nesters for snags of this size. Smaller snags were not selected. Carey et al. (1991) and Lundquist and Mariani (1991) also found greater use of larger snags. Since flying squirrels, an owl prey species, are secondary cavity users, management for higher densities of primary cavity-nesters will benefit squirrels and, indirectly, owls. Retention of all snags more than 20-inch dbh will maximize the number of residual snags available to flying squirrels, while providing important habitat for bird species responsible for the excavation of cavities used by squirrels.

Application of the guidelines for salvage to an old-growth forest in the Oregon Cascades will provide retention of an average of 17 Douglas-fir and 9 hemlock snags per acre based on mean live-tree densities (Table 3.1) for those forests (Spies pers. comm.). Because of the diversity of initial diameters, predicting snag population survivorship is complex. However, projections based on decay rate constants of Harmon et al. (1986) suggest that about two Douglas-fir snags per acre will remain in 100 years. The equations of McComb and Ohmann (pers. comm.) predict that as many as four to six Douglas-fir and one hemlock snags per acre may persist. These estimates are within the range of densities commonly found in naturally regenerated stands at that age (Carey et al. 1991, Huff et al. 1991, Spies and Franklin 1991).

Table 3.1. Live tree densities in example old-growth western hemlock/Douglas-fir stand prior to stand-replacing fire.

	Stem Density per Acre by Size Class				
	2 to 4 inches	4 to 20 inches	20 to 40 inches	40 to 60 inches	60 inches+
Douglas-fir	10	17	8	7	2
Western hemlock	23	33	8	1	0

After 100 years residual snags will be well decayed and about half will be more than 15 feet tall (Spies and Franklin 1991). Not all snags will have cavities for flying squirrels. In mature forests (80 to 195 years old) in western Oregon and Washington, an average of 8 percent of snags more than 20-inch dbh contained natural cavities and 24 percent had excavated cavities (Spies and Franklin 1991). Even if natural and excavated cavities were in different snags, only about 30 percent of all snags would have cavities, and post-fire retention of all snags more than 20-inch dbh may only provide one or two residual snags per acre with cavities. It is prudent initially to retain maximum numbers of large snags to provide for long-term needs of cavity-nesters, including flying squirrels.

In this scenario, approximately 17 Douglas-fir and 44 hemlock stems per acre between 4- and 20-inch dbh would be available for salvage. The volume probably would be similar to that removed during commercial thinning. Application of the snag guideline provides for maximum densities of snags at 100 years, while allowing removal of smaller diameter stems which would not persist.

Log Retention

In the western Oregon Cascades and Oregon Coast Range, most naturally regenerated conifer forests contain 9 to 18 tons per acre of down logs at 100 years of age (Spies et al. 1988). Assuming a 3 percent annual decay rate (Spies et al. 1988) for 100 years, about 180 tons per acre of CWD need to be retained to provide this quantity. Therefore, approximately 50 to 75 percent of the original standing biomass of 270 to 360 tons per acre (Spies et al. 1988) must remain on the site. Down logs with diameters greater than 20 inches should be retained selectively. These larger logs will decay relatively slowly and provide habitat for forest floor mammals during a relatively long time period (Carey and Raphael pers. comm.).

If regeneration is delayed, significantly greater amounts of CWD must be retained to compensate for delaying CWD production by the new stand 100 years hence. Thus, when areas are salvaged, it is extremely important to regenerate new stands as quickly as possible.

If green trees, snags, and logs are on site following the disturbance, guidelines to retain all green trees and all snags with diameters greater than 20 inches will be applied first. The guideline for logs will reflect the amount of biomass left in the form of snags since this standing material eventually will become available as CWD. For example, if snags were estimated to provide 90 tons per acre, this amount will be deducted from the 180 tons per acre required to be left as logs.

In any case, where the combined biomass of snags and logs greater than 20 inches in diameter do not meet retention objectives (e.g., 180 tons per acre in western Oregon and Washington Cascades), additional logs and/or snags of smaller diameter will be retained.

Guidelines to Reduce Risks of Large-Scale Disturbance. Large-scale disturbances are natural events, such as fire, that can eliminate owl habitat on hundreds or thousands of acres. Certain risk management activities, if properly planned and implemented, may reduce the probability of these major stand-replacing events. There is considerable risk of such events in DCAs in the eastern Oregon and eastern Washington Cascades and the California Cascades provinces and a lesser risk in the Oregon and California Klamath provinces (as documented in Appendix F). Elevated risk levels are attributed to

changes in the characteristics and distribution of the mixed conifer forests resulting from fire protection. These forests have had repeated insect infestations and are susceptible to major fires. Risk reduction efforts are encouraged where they are consistent with the overall recommendations in this section.

Silvicultural efforts will focus on currently unsuitable habitat in DCAs to accelerate development of suitable conditions for owls while making the future stand less susceptible to natural disturbances. Salvage activities will focus on the reduction of insect, disease, and fire threats. Treatments will be designed to provide effective fuel breaks wherever possible. However, the scale of salvage and other treatments must not result in erosion of currently suitable owl habitat.

Guidelines for Coordination of Other Multiple-Use Activities. A variety of activities currently occur in DCAs or may be proposed in the future. The highest priority of DCA management is to meet owl needs and promote recovery, and all activities will be evaluated in that regard. The type and extent of multiple-use activities will vary among DCAs, and will be reflected in DCA management plans. It will be necessary to modify or eliminate activities that pose adverse impacts, and impose seasonal or other appropriate restrictions on some other proposed actions. This may require the revision of management guidelines, procedures, or regulations governing these multiple-use activities.

Assessment of all multiple-use activities within one-quarter mile of the known owl activity centers, to determine their effects on owl reproductive success, will be included in DCA management plans. Between March 1 and September 1 of each year, activities which may disrupt owl breeding will be prohibited under the management plan.

The following guidelines address activities most likely to require attention in DCA management plans.

1. **Road Construction and Maintenance.** Transportation needs must be assessed for the DCA itself and for adjacent areas. The assessment should consider all existing and planned activities within the DCA. Access to nonfederal lands through DCAs will be considered and existing rights-of-way agreements must be recognized as valid existing rights. A determination will be made if existing roads are needed or if closure and rehabilitation is appropriate. Future needs of road access for fire protection must be considered when identifying roads for closure and rehabilitation.

   Road construction in DCAs for silvicultural, salvage, and other activities generally is not recommended, unless potential owl habitat benefits clearly exceed potential costs of habitat impairment. If new roads are necessary to execute a practice that is otherwise in accordance with these guidelines and an approved DCA management plan, they will be kept to a minimum, be of a temporary nature, be of the lowest standard possible to accomplish the intended purpose, and be routed through unsuitable habitat where possible. Where economically feasible, aerial logging systems will be used instead of new road construction.

   New road construction through DCAs may be necessary to access nonfederal lands. In these cases, alternate routes that avoid the DCA should be considered. If roads must be routed through a DCA, they will be designed and located to have the least impact on owls and owl habitat. New roads will not be constructed through suitable owl habitat unless no other feasible alternatives exist.

2. **Fuelwood Gathering.** If allowed, fuelwood gathering will be restricted to existing cull decks, blowdown blocking roads, or green trees marked by silviculturists to thin overstocked unsuitable habitat. These areas will be mapped during preparation of the DCA management plan and mitigation recommendations will be included.

3. **Mining.** The impacts of proposed mining actions should be assessed, and mineral activity permits will include appropriate conditions (e.g., seasonal or other restrictions) related to all phases of mineral activity.

4. **Developments.** In general, construction or development of new facilities that may adversely affect owl habitat or reproductive success will not occur within DCAs. Proposals that address public needs or provide significant public benefits, such as powerlines, pipelines, or other public works projects, will be reviewed on a case-by-case basis and may be approved when adverse effects can be minimized and mitigated. Whenever possible, such projects should be anticipated and addressed in DCA management plans.

5. **Trail Development.** New trail construction will be planned to have the least possible adverse effect on owls. Trails will be located at least one-quarter mile from owl activity centers and otherwise avoid adverse modification of suitable owl habitat.

6. **Land Exchanges.** Land exchanges in DCAs will be considered when they will either promote owl recovery or provide owl benefits equal to current conditions at a lower cost.

7. **Habitat Improvement Projects.** Projects designed to improve conditions for fish, wildlife, watershed, range, or recreation will be considered if they provide owl habitat benefits or enhance the likelihood of reproductive success. Other projects will be considered if their effect on owls or owl habitat is negligible. These may include small projects required for recovery of other threatened or endangered species. In all cases, appropriate project management will be provided. For example, watershed rehabilitation projects, such as felling trees along streams, will be coordinated with a wildlife biologist and include seasonal restrictions.

8. **Range Facilities.** Range-related facilities that do not affect owls or owl habitat adversely will be developed in coordination with wildlife biologists. Existing grazing activities which have an adverse effect on owl habitat or owl use of the area will be modified.

9. **Fire Suppression and Prevention.** Fuels management within the DCA will be in accordance with guidelines for reducing risks of large-scale disturbances. Plans for wildfire suppression will emphasize maintaining owl habitat within the DCA. During actual fire suppression activities, a resource specialist familiar with the area and the DCA management plan will be included to assure that habitat damage is minimized.

10. **Christmas Tree Sales.** Christmas tree sales will be allowed in areas where trees are removed in accordance with the objective of accelerating the development of suitable habitat conditions in areas that currently are unsuitable. The guidelines for silvicultural activities will be used as appropriate.

11. **Minor Forest Products.** Minor commercial uses, such as the collection of ferns, mosses, and mushrooms, generally will be allowed. Where these activities are extensive (e.g., collection of Pacific yew bark), it will be

appropriate to evaluate whether they have significant effects on owl habitat. Restrictions may be appropriate in some cases.

12. **Recreational Uses.** Dispersed recreational uses, including hunting, generally are consistent with the objectives of DCAs, except as specifically noted elsewhere in the draft recovery plan.

13. **Research.** A variety of wildlife and other research activities (e.g., water quality) may be proposed in DCAs. These activities must be assessed to determine if they are consistent with DCA management guidelines. If agencies address the range of these activities explicitly in DCA management plans, disruption of existing research or disincentives for proposed research may be avoided, particularly in the case of small and widely dispersed experimental forestlands.

14. **Rights-of-Way, Contracted Rights, Easements.** Existing and proposed agreements will be evaluated and revised where feasible. In some cases, preexisting agreements may pose legal issues or raise other concerns that require consideration in the DCA management plan.

b. Other Federal Lands

For the purposes of the recovery plan, the "matrix" is defined as lands within the range of northern spotted owls which are outside DCAs. This discussion is specific to federal matrix lands. Recovery contributions from nonfederal matrix lands are described in section III.C.4.

Federal matrix lands will make several essential contributions to recovery. Their most basic function is to help maintain adequate habitat conditions to allow movement of owls among DCAs. As described in section III.B., this interchange among DCAs is necessary to allow functioning of the whole spotted owl population. The second function of the matrix is to maintain reproductive owl pairs, where possible, in areas where DCAs cannot fully meet the criteria (section III.C.2) established by the recovery plan. These pairs will help supplement DCAs where owl populations or habitat are deficient until those deficiencies can be corrected. In some cases, population deficiencies in DCAs may not be corrected for a long period of time and owl pairs in the matrix will remain a part of the recovery strategy for the foreseeable future. In other areas, the matrix will be required to support pairs of breeding owls as a safeguard against the possibility of large-scale loss of habitat in DCAs from fire, insects, and disease. Finally, the matrix will contain areas of nesting habitat that will preserve options to reestablish owls throughout the landscape.

Since habitat conditions and owl populations vary across the range, specific objectives for matrix forests also will vary. Four matrix management prescriptions have been identified. Criteria were developed to determine where these prescriptions will be applied. Those criteria and the implementation guidelines are described in this section. The province narratives (section III.C.4) identify the locations where the prescriptions will be applied and the approximate acreages involved.

Recommendations for federal matrix management provide for a broader mix of activities than the recommendations for the DCAs. It is expected that a wide variety of commercial timber activities will occur within the matrix, with their timing and location designed to meet the conditions specified for the matrix. For several matrix management prescriptions, the acres on which habitat goals are met may shift through time. For other prescriptions, such as the reserved pair areas, tighter controls on activities are recommended.

The application of prescriptions A, B, and C is essential to achieve recovery. Prescription D is recommended as a supplement to prescription A and could speed recovery of the species while providing benefits to other species.

PRESCRIPTION A — MAINTAIN DISPERSAL HABITAT AND ACTIVITY CENTER

Management objective

Provide habitat to support dispersing owls and maintain residual habitat areas that protect activity centers for pairs and territorial singles in the matrix. The other matrix prescriptions are supplemental to this minimum requirement.

Discussion. The minimum role of the matrix is to provide habitat conditions adequate to assure at least short-term survival of a significant proportion of dispersing owls (see sections II.A. and III.B.) To achieve species recovery, the matrix must play this role. The matrix also must protect a given number of owl activity centers referred to as residual habitat areas. The size requirement for residual habitat areas is based on information about home ranges used during the breeding season. These areas will not meet long-term needs of owls. However, they will provide areas of high-quality habitat for dispersing owls, prevent the direct elimination of nesting areas, and provide cores of suitable habitat to preserve future options for managing owls in the matrix. Given the recovery objective to reestablish owls throughout the landscape, providing residual habitat areas is essential.

Criterion for applying prescription

Management to achieve these minimum matrix objectives will be practiced on federal lands throughout the range of the owl where forests are sufficiently productive to attain the conditions specified.

Management guidelines for prescription A

1. The number of residual habitat areas to be provided is based on densities of owl pairs observed in study areas. These target densities vary by province where appropriate (Table 3.2).

Table 3.2. Density of residual habitat areas

Physiographic Province	Areas Per Township
Olympic Peninsula	4
Western Washington Cascades	6
Eastern Washington Cascades	6
Western Oregon Cascades	8
Eastern Oregon Cascades	6
Oregon Coast Range	8
Klamath (Oregon and California)	10
California Coast Range	10
California Cascades	6

2. Residual habitat areas will be provided for all known and newly discovered pairs and territorial singles up to this density.

3. Each residual habitat area will include a minimum of 100 acres of suitable habitat as close to the nest site or activity center as possible. This is intended to preserve an intensively used portion of the breeding season home range. Timber management within this area is not appropriate. Management around the area will be designed to reduce the risks of natural and human-caused disturbance.

4. At least 50 percent of the federal forest matrix outside of the DCAs will be managed to provide stands of trees that average at least 11 inches dbh and have at least 40 percent canopy closure. This guideline will be applied on each quarter-township, and will be calculated based on the amount of federal land within that quarter-township. Calculation should be made separately for lands managed by each of the federal agencies. All forested land that is capable of attaining the 11-inch dbh standard and the 40 percent canopy closure standard will be included in the calculation. Hardwoods may be included in meeting the canopy closure guideline, but excluded from the diameter calculation where they normally do not attain that size. Canopy contribution will be counted only for evergreen hardwoods. There should be reasonable flying space under the hardwood canopy (i.e., 6 or more feet between the bottom of the hardwood canopy and the top of the shrub layer). Reserved pair areas (see matrix prescription B), managed pair areas (see matrix prescription C), and residual habitat areas may be included in the calculation.

   In general, a stand meets the guideline if the tree of average basal area is at least 11 inches dbh and the total canopy closure is more than 40 percent. However, where there is much variation in dbh, the intent is that 40 percent canopy closure be contributed by trees which meet the 11-inch dbh standard.

PRESCRIPTION B — SUPPLEMENT DCA NETWORK

Management objective

Provide habitat (reserved pair areas) for pairs and territorial singles in the matrix to supplement the DCA network where the network is deficient because it fails to meet: 1) spacing criteria; 2) criteria for existing habitat acreage; and/or 3) criteria for either existing pairs or future pairs.

Discussion. Existing habitat and landownership conditions make it impossible to implement a fully adequate network of DCAs across the owl's entire range. At numerous locations the existing distribution of habitat and/or owls necessitated deviation from the size, spacing, or owl numbers criteria (section III.C.2). Where these deficiencies are significant, it is important to supplement the DCAs by maintaining additional suitable habitat and owl locations in the matrix. This reinforcement of the matrix population will improve stability of the owl population in the DCA and provide additional assurance of dispersal success across the matrix.

Criteria for applying prescription

Reserved pair areas will be established where any of the following conditions occur:

Category 1 DCAs contain less than 15 currently known pairs and territorial singles, or have a current expected capability to support fewer than 20 pairs of

owls. (Refer to tables in section III.C.4, for identification of these areas.) See management guidelines 1 and 2 (later in this section) for actions to be taken in these cases.

Category 1 DCAs are more than 12 miles apart, or category 2 DCAs are more than 7 miles apart. If category 2 DCAs are relatively large (i.e., 10 pairs), then it may be appropriate to modify this criterion to allow greater distances than 7 miles. See management guideline 3 for action to be taken in this case.

Other areas are identified on a case-by-case basis. These could include areas where 1) only small category 2 DCAs (i.e., two-pair areas) could be delineated or 2) where overall owl densities in the DCA network fail to meet densities that would be obtained if all guidelines (section III.C.2) for the DCA network were fully met. See management guideline 3 for action to be taken in this case.

Management guidelines for prescription B (assumes implementation of prescription A)

1. In areas where DCAs do not currently contain sufficient owl pairs and territorial singles, provide reserved pair areas for matrix pairs or territorial singles to increase to 15 the total known owl activity centers associated with a given category 1 DCA. The standard here is set at 15 known pairs or territorial singles rather than 20 because some pair sites in a DCA might not be occupied at any given point in time. This value was derived from a table of expected occupancy of areas given different numbers of interacting pair sites and different amounts of suitable habitat in the area (Voss and Noon pers. comm.).

2. Where category 1 DCAs contain inadequate suitable habitat to support at least 20 owl pairs, reserved pair areas will be established so that the total amount of habitat associated with a given category 1 DCA is adequate to support 20 owl pairs.

3. For areas that do not meet the distribution distance criterion, or other special emphasis areas, provide enough reserved pair areas so that the total pair density at least equals that which would be obtained if all guidelines for the DCA network were met. This density is two pairs per township.

4. To identify reserved pair areas, search for pairs and habitat that are as close as possible to the DCAs.

5. For each reserved pair area, delineate an area surrounding the activity center with an acreage at least equal to the median home range size for pairs. Use data from the study area that is most similar to the site being considered (Table 2.1). This area will be delineated to encompass as much suitable habitat as possible, and that habitat will be as close to the acti-vity center as possible. Reserve all suitable habitat within that area from timber harvest. If this habitat acreage does not at least equal the median amount found for pairs in the province (Table 2.2), additional habitat must be provided from 1) the next best habitat available within the home range area, or 2) additional habitat outside the home range area.

6. Within these reserved pair areas, allow for management of currently unsuitable areas consistent with DCA management guidelines.

7. Wherever located, reserved pair areas will count toward the residual habitat area densities for prescription A. Residual habitat areas which are not required as reserved pair areas will continue to be managed under prescription A.

PRESCRIPTION C — REDUCE THREAT FROM DISTURBANCE

Management objective

In addition to the minimum requirements of prescription A, provide habitat (managed pair areas) for pairs and territorial singles in the matrix to supplement DCA populations in areas where there is significant threat of large-scale disturbance in DCAs.

Discussion. The probability of large-scale disturbances in DCAs in different provinces across the range of the owl was assessed by Agee and Edmonds (Appendix F). In the Oregon and California Klamath provinces and the eastern Cascades provinces of Oregon and Washington, there is significant probability of large-scale disturbances to the majority of DCAs due to insects, diseases, and fires.

Several factors help to compensate for this potential threat to the DCA network. First, design of the DCA network helps to buffer owl populations against catastrophic loss in any individual DCA. Second, as noted in section III.C.2. and Appendix F, some forms of active management (e.g., fuels management) may help to reduce the risk of large-scale disturbance within the DCAs. Finally, prescription C calls for innovative management to be used within the matrix to help provide for breeding owls in these managed forests. This will reduce the dependence of owl populations on the DCA habitat.

Criterion for applying prescription

For application of this prescription, an area must lie within high-risk portions of provinces identified by Agee and Edmonds (Appendix F) as having a low probability of long-term maintenance under a strategy where habitat is not managed but is protected from fire. This prescription will be applied immediately to the eastern Washington Cascades province because the spotted owl population in that province is at high risk from large-scale disturbance and is essential to support the overall owl population in Washington. Application of this prescription to the eastern Oregon Cascades, the California Cascades, and the Oregon and California Klamath provinces also should be considered but is not included as an immediate recommendation.

Management guidelines for prescription C (assumes the implementation of prescription A)

1. For all pair or territorial single activity centers identified under prescription A, provide additional suitable habitat in an area approximating the size of a pair home range surrounding the activity center.

   The size of this area will be determined from median home range data for the province (Table 2.1). Use data from the study area that is most similar to the site being considered. The amount of suitable habitat within this area will approximate the median amount observed within pair home ranges for that same study area (Table 2.2).

2. This habitat may be maintained through time using various management techniques. Some uncertainty will be accepted in the use of management to provide habitat in these areas. Management will be designed to provide suitable habitat conditions and to alleviate the forest conditions leading to significant threat of large-scale disturbance. Refer to Appendix G for examples of management techniques useful in providing for suitable habitat conditions through time.

PRESCRIPTION D — RETAIN OWLS IN MANAGED LANDSCAPE

Management objective

In addition to the minimum requirement of prescription A, use a combination of silvicultural manipulations and habitat reserves to permanently support owl pairs and territorial singles. This is recommended in order to: 1) reduce the overall decline in population; 2) move toward total landscape management for owls; 3) provide opportunities to experiment with specific habitat management techniques, and 4) provide benefits for other species. While prescriptions A, B, and C are essential for recovery, prescription D is recommended to speed recovery but is not considered essential.

Discussion. The long-term goal of the recovery plan is to move from a landscape composed of protected areas and matrix toward a landscape where conditions provide for a more continuous distribution of owls. Unfortunately, many of the actions that might be taken in the short-term could impede rather than promote achievement of this goal. Effective pursuit of the goal requires three management commitments. First, some active forms of management in currently unsuitable younger stands within the DCAs should begin. Second, such techniques also should be applied in unsuitable habitat in the matrix to facilitate the development of suitable habitat in the matrix. Finally, there must be efforts to retain owls and suitable habitat in the matrix and to begin experimenting with active forms of management that will sustain habitat over time. Such management could include uneven-aged silviculture and management on long rotations. The latter two actions to support owls in the matrix will have a variety of benefits, including slowing the expected rate of overall owl population decline and possible benefits to other species (see Appendix D).

Application of this prescription may be particularly beneficial in several instances. It may be useful in areas where owls exist at relatively high densities well-distributed over the landscape. An example of such an area is the western Oregon Cascades province. Implementation of the DCA strategy in this province without additional measures in the matrix could result in a significant decline in the owl population. Such a decline would retard progress toward recovery.

Conversely, it may be beneficial to retain owls in the matrix in areas where the population outside DCAs is sparse. In such cases, removal of the few remaining owls from the matrix also seriously will impede the long-term goal to manage for owls across the landscape.

In addition, it would be useful to apply the prescription where it can benefit other species in the following categories:

1. Federally listed species or candidates for listing known to be associated with older forests.

2. Species with restricted ranges and associations with older forests where their ranges are not substantially included in existing DCAs.

Criterion for applying prescription

This prescription could be applied in any part of the matrix.

Management guidelines for prescription D (assumes the implementation of prescription A)

1. Provide managed pair areas in an area approximating the size of a pair home range surrounding the activity center. The size of this area and

amount of suitable habitat should be determined from home range data for study sites most similar to the site being considered (Tables 2.1 and 2.2). This habitat may be maintained through time using various management techniques. Some uncertainty will be accepted in the use of management to provide habitat in these areas. This habitat is not a requirement of recovery.

2. As an alternative, habitat may be provided and distributed throughout the matrix area rather than focused on owl activity centers. For example, the objective for matrix management could be to maintain 10 percent superior habitat and 20 percent marginal habitat (Thomas et al. 1990) in the matrix at all times. A combination of habitat retention and habitat management could be used to achieve the objective, with existing allocations contributing where they provide appropriate conditions. Under this alternative, residual habitat areas still would be a requirement. The acres in residual habitat areas will contribute to the total that is to be maintained as superior habitat.

III.

C.

3. Implementation

Federal lands

Federal agency planning.

Federal agencies should review the draft recovery plan to determine if it provides adequate assurance of recovery and can be implemented in an efficient manner. The Recovery Team will review agency comments on the draft plan and will work with the agencies to incorporate their comments in the final recovery plan.

The recovery plan was prepared under the assumption that agency activities submitted for consultation after January 1, 1993, will be consistent with its recommendations. Actions in areas of special concern should be made consistent with the recovery plan as soon as the final plan is approved. If agencies act inconsistently with the recovery plan for an extended period, reductions in owl populations and in the amount and quality of owl habitat could have results that were not anticipated during the plan's development. Such reductions might require a reevaluation of the recovery plan to determine whether it would still provide sufficient assurance of recovery.

After the final recovery plan is approved, federal agencies, the states, and the private sector will need advice and assistance on various aspects of implementation. The recovery plan recommends the establishment of a coordinating group to carry out these functions (see section III.C.5.). The group should be established upon approval of the final recovery plan or as soon thereafter as feasible. The Recovery Team should remain in existence to provide advice and necessary support until the coordinating group is established.

Implementation of the recovery plan will require that agencies with authority over forestlands comply with other legal mandates in addition to the Endangered Species Act. The BLM must implement the recovery plan in a manner consistent with the Federal Land Policy and Management Act (FLPMA) and National Environmental Policy Act (NEPA). The Forest Service must implement the plan in a manner consistent with the National Forest Management Act (NFMA) and NEPA. Full implementation of the recovery plan should be completed within 5 years. The anticipated schedule for implementation is outlined in section III.C.3.

Critical Habitat Designation.

The recovery plan recommends that federal lands in DCAs, other than national parks and wilderness areas, be designated as critical habitat for the northern spotted owl. The Recovery Team does not recommend designation of any other areas as critical habitat at this time. If progress toward reaching recovery goals does not proceed as quickly as anticipated, then designation of additional critical habitat may become appropriate in the future. The FWS should initiate efforts to revise designated critical habitat as soon as the recovery plan is approved.

DCA Management Plans.

The recovery plan recommends that management plans be prepared for each designated conservation area (DCA). These plans are an essential component of the effort to implement recovery, as they will provide a framework and objectives for carrying out specific activities, monitoring their progress, and evaluating contributions toward recovery. The Recovery Team therefore recommends that the Forest Service, the BLM, and the National Park Service initiate efforts to prepare these plans at an early date. Where practicable, plans for areas of concern should be given priority. Guidelines for preparation of these plans are contained in section III.C.2. and Appendix E. The suggested coordinating group would provide further guidance upon request from the agencies.

Consultation with the FWS.

At the request of the FWS, the Recovery Team has considered some of the issues that must be addressed during consultation.

1. *Programmatic consultation.*

   Federal agencies may consult with the FWS on site-specific actions, such as proposed timber sales, or on programmatic actions, such as a proposed forest plan. In a programmatic review, the FWS considers impacts of a series of proposed actions that subsequently may be carried out during a period of several years. This approach is far more appropriate than attempting to evaluate the effects of each separate action. Programmatic review also is beneficial for the land management agencies because once consultation is complete, activities taken in accordance with the proposed program and the biological opinion may occur without further FWS review (unless new information is discovered that warrants reinitiation of consultation). Programmatic consultation also increases efficiency, thereby enabling the FWS to increase the technical assistance it provides to agencies. Consequently, the recovery plan recommends that consultations related to implementation of the recovery plan be carried out on a programmatic, rather than site-specific, basis.

   Agency proposals to adopt the final recovery plan would be appropriate for consultation and would facilitate programmatic review of activities affecting the owl. "Adopt," in this context, means making a formal commitment in a record of decision of other similar document 1) to establish DCAs in a manner consistent with the recovery plan's recommendations, and 2) to follow the guidelines for managing the DCAs and the matrix. Such a document would provide an adequate basis for completion of consultation on activities in the matrix. Specifying impacts in DCAs in sufficient detail to complete consultation may be difficult until a DCA management plan is approved. Consultation should be initiated prior to any action in DCAs that might affect northern spotted owls until a DCA management plan has been approved and section 7 consultation on the plan has been completed.

2. *Rate at which take may occur without compromising recovery.*

   The recovery plan includes several components designed to ensure that incidental take does not occur too rapidly in the matrix. Reserved pair areas and managed pair areas will be established in the matrix, an intensive monitoring program will be initiated, and the recovery plan will be reviewed and revised periodically. The planning processes in the federal agencies also restrict the rate at which habitat, and thus owl populations, will disappear in the matrix. These measures should provide adequate constraints on the rate at which incidental take occurs.

3. *Activities that may result in destruction or adverse modification of critical habitat.*

The recovery plan establishes guidelines for the management of DCAs and the preparation of DCA management plans. The Recovery Team recommends that the FWS use these guidelines in determining whether proposals for actions within DCAs, or for adoption of DCA management plans, would result in the destruction or adverse modification of critical habitat. The recovery plan recommends that critical habitat be revised to conform with DCA boundaries, and recommends, in the interim, that the FWS utilize the matrix management prescriptions (section III.C.2.) in analyzing the impact of actions in critical habitat outside of DCAs.

4. *Relationship between agency actions.*

The Recovery Team considered the potential relationship between the actions of different agencies. Clearly, recovery will be achieved more rapidly and effectively if all agencies comply with the recovery plan in a timely manner. Substantial lack of compliance could delay or preclude recovery. Agency actions that do not comply with the recovery plan will be required to individually satisfy the mandate of section 7 consultation in terms of adverse modification of critical habitat or jeopardy to the species. However, the accumulated impacts of actions not consistent with the recovery plan could eventually necessitate redesign of the recovery plan in a particular area. This may result in greater restrictions on timber harvest activities, including those of agencies that have complied with the recovery plan.

Past and current actions of each agency affect other agencies through impacts on the rangewide habitat condition and spotted owl populations. Impacts of actions that may affect spotted owls are evaluated in light of this baseline condition. However, due to location and ownership patterns, the recovery plan envisions little opportunity to substitute greater contributions from one agency for lesser contributions from another. This is particularly true in the case of DCAs, but also applies to the matrix. Consequently, the recovery plan generally anticipates that, during the next few years, actions proposed by one agency are unlikely to significantly affect the outcome of consultations on actions proposed by other agencies.

Nonfederal lands

The explicit federal duties described in the Endangered Species Act, combined with the concentration of northern spotted owls on lands administered by the Forest Service and BLM, give the federal government a dominant role in providing for recovery of the species. Nonfederal lands, however, comprise important portions of the spotted owl's range where federal contributions alone are not sufficient to meet recovery goals. Recovery goals for each province contain objectives for nonfederal lands, although the amount and type of contribution vary (see section III.C.4.).

Current protection afforded spotted owls on nonfederal lands derives from the Endangered Species Act's prohibition against the taking of listed species. The FWS developed biological guidance in July 1990 for reducing the risk of violating the take prohibition. The guidance recommends that landowners survey for spotted owls prior to timber harvest and avoid reducing habitat below prescribed amounts within circles around nests or activity centers (Section II.C.). This protection applies unless effective alternate measures are implemented through habitat conservation planning (under section 10 of the

Endangered Species Act) or through regulations adopted in compliance with section 4(d) of the act.

Several measures are available to achieve recovery through alternatives that would be more effective than maintenance of the current take circles (see tools for implementing recovery on nonfederal lands in this section). Recovery goal implementation likely will differ by state due to the variations in the degree of federal ownership by province, states' authorities, and availability of information about the owls. Protective management, which encourages creative approaches to recovery goal implementation, is a likely alternative to maintenance of take circles. States, landowners, the FWS would negotiate with state wildlife agencies and other interested parties to develop a plan to improve species protection and landowners' ability to manage their land. The Endangered Species Act allows protective management to serve as the basis for either conservation plans (section 10 of the Endangered Species Act) or special rules (section 4(d)).

Incentives to Participate in Protective Management.

Biologists, landowners, communities, and government agencies share several incentives to participate in protective management:

1. *Management flexibility for owl protection and timber harvest planning.*

   A plan could tailor protection to fit the owl population's long-term habitat requirements, with less emphasis on short-term protection of individuals and pairs. Long-term protection could be adjusted across the landscape to improve the configuration of owl habitat blocks and to complement reserves on federal lands more effectively. The FWS could authorize an increased level of take if assurances were provided by landowners that long-term, effective mitigation efforts would be implemented providing the needed level of support for recovery. Measures such as designating certain areas to be protected or instituting FWS-approved habitat management plans might be more attractive to landowners than continuing take circles and annual surveys.

2. *Certainty of owl protection and timber harvest planning.*

   Landowners would manage for long-term owl habitat needs, providing a better guarantee of habitat than the transient and potentially vulnerable circles (see section II.C.). Landowners then could plan timber harvest based on the certainty of knowing which areas would be affected by owl protection.

3. *Cost reduction of owl protection.*

   Perhaps the most compelling incentive for landowners to participate in an alternative conservation program is a significant reduction of the costs of owl protection they now incur including: a) maintenance of habitat within current take circles; b) conducting annual owl surveys; and c) administrative costs associated with compliance with state forest practices regulations protecting listed species (see section II.C. for description of each state's regulations).

4. *Authorizing incidental take in exchange for implementing conservation measures identified in the recovery plan.*

   Consistent with the Endangered Species Act, landowners could be authorized a level of incidental take through the HCP or 4(d) process if they are

found to exceed protection called for in the conservation objectives, allowing them to plan future timber harvests (see section II.C.).

5. *Relaxation of owl conservation requirements on federal lands in response to increased efforts on nonfederal lands.*

   Some nonfederal landowners are more willing to contribute to owl recovery if they see that their efforts can lead to a reduction of conservation required on federal lands.

Guidelines for protective management.

1. Protective management should provide for the identified recovery objectives for nonfederal lands while placing the minimum burden on landowners necessary to achieve those conservation objectives.

2. Explicit goals for nonfederal lands should describe when recovery would be reached and how a landowner's efforts would contribute to overall recovery. Protective management should be based on the recovery plan's identification of the amount, spatial and temporal configuration, and function of the necessary habitat; and the target number of individuals and population trends required to meet delisting goals. The protective management plan should describe the specific implementation actions needed to implement the recovery plan's provincial goals.

3. Incentives, rather than disincentives, should be provided for finding owls, when consistent with the Endangered Species Act. Possible incentives include: a) landowner flexibility in where they protect habitat, b) reduction of total area required for protection, c) off-site mitigation for owl protection, or d) relaxation of restrictions on adjacent federal lands. Based on the recovery plan's description of contribution from nonfederal lands, landowners could be authorized some amount of incidental take where conservation measures had been implemented.

4. A protective management plan should explain the variation in owl protection requirements based on biological and physiographic distinctions and the degree of federal conservation by province, so that the public will understand the basis for differences in federal and state owl protection regulations.

5. Protective management plans should start with the recovery plan's assessment of the take prohibition.

   The protective management plan should be based on the recovery plan's general assessment of the amount and rate of incidental take that can be allowed on nonfederal lands where conservation mechanisms are being put into place to accomplish recovery goals for a province. The protective management plan should identify where implementation of province recovery objectives cannot allow incidental take. Where possible, the allowable amount and rate should be identified. The form and pattern of landowner contribution to recovery can be negotiated. If areas are identified where protection of individual owls is not essential for conservation, incidental take could be permitted with minimal mitigation required. The protection of owls beyond the level needed could be considered as mitigation for impacts on owls in other nearby areas.

   Land purchase and exchange should be considered for nonfederal areas essential to recovery that do not have take prohibitions to serve as an incentive to negotiate conservation with landowners.

6. Costs to landowners should be reduced.

   The protective management plan should identify and analyze the cost of conservation options, and encourage selection of the lowest cost option.

   The protective management plan should minimize the cost of owl protection for small acreage landowners who are less able than their neighbors with larger acreages to negotiate owl protection. Take circles may cover a substantial portion of their land, often for owls on adjacent ownerships, disproportionately restricting access to their small holdings. The conservation plan could recommend that these landowners contribute to conservation in an alternative manner.

   The cost of protective management itself should be paid in such a way that landowners' incentive of cost reduction is not eliminated. If landowners are required to bear the full cost of protective management, they may find that the planning costs outweigh savings from changes in take prohibitions. For instance, state wildlife agencies could be funded to help landowners write the plans.

7. The protective management plan should recognize the role of state regulators. The plan should acknowledge the extent to which states have the authority to: a) enforce an agreement between the FWS and landowners; and b) conform state regulatory measures to the requirements of the plan. States also may have requirements independent of take prohibitions that should be assessed in the plan.

8. The feasibility and timing of implementation, such as the development of new state rules, legislative actions, board/commission approval of rules, and availability of funding, should be assessed.

Habitat Conservation Plans. Habitat conservation plans (HCPs) (see Section II.C.4.) provide an excellent opportunity for nonfederal landowners to participate in the development of protective management plans. California has been developing HCPs for northern spotted owls during the past few years. A few companies have developed HCPs and signficiant progress has been made on developing a statewide HCP. These efforts should be assisted and encouraged by the Recovery Team.

Regulations under section 4(d) of the Endangered Species Act.

For endangered animals, section 9 of the act directly prescribes prohibitions against taking. Take is defined broadly under the act as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct." For threatened animals, section 4(d) of the act directs the Secretary to adopt "such regulations as he deems necessary and advisable to provide for the conservation of such species." The regulations applied for a threatened species may adopt any or all of the prohibitions applied by section 9 for endangered species. Since 1975, general regulations (50 CFR 17.31) have applied the full range of taking prohibitions for threatened animal species, but also have provided for the alternative of adopting special rules for particular species as necessary and advisable. The FWS has adopted special rules for more than 30 species.

Potentially, the special rule mechanism could provide great flexibility to apply taking prohibitions for the owl in those ways most likely to promote its conservation. A well-crafted special rule framework could incorporate many of the characteristics of a habitat conservation plan. Any set of rules adopted would have to pass the test of being necessary and advisable to promote the owl's conservation and would be subjected to public review in a rulemaking process.

These requirements would tend to ensure that special rules would permit take only when a more effective program (that provided long-term assurance that recovery would occur) had been implemented.

As envisioned by the Recovery Team, one possible role for federal special rules would be to ratify owl protection measures implemented under state authorities. For example, a state would adopt regulations governing the harvest of owl habitat on nonfederal lands including measures aimed at maintaining currently unoccupied habitat in some areas and possibly other measures aimed at developing owl habitat in areas where it does not now exist or is in short supply. In areas where nonfederal contributions to recovery do not require absolute prohibition of taking, restrictions on harvest might be substantially less than those that now apply under federal regulations. Federal rules might then prohibit deliberate, nonincidental taking and taking in violation of state regulation. The owl would gain benefits not available under the general taking prohibition in areas that now have no owls, and landowners would be relieved of some of the current taking restrictions within occupied owl habitat.

Another possible arrangement can be imagined that, for instance, would place more of the substantial restrictions within the federal rules or would allow various means of off-site mitigation for harvest under state regulations. Close cooperation between the FWS and the states would be necessary in the planning of any such arrangement to ensure that state regulatory authorities were adequate for implementation and that any regulation adopted would satisfy the standards of the Endangered Species Act. The adoption of federal regulations also would be subject to review under NEPA and Executive Order 12291, which requires assessments of the impacts of federal rules.

Building a climate for negotiating protective management.

Landowners are not required by the Endangered Species Act to contribute any spotted owl protection beyond their obligation to refrain from taking owls. If spotted owl recovery depends in part on conservation efforts on nonfederal lands, a climate for negotiation between landowners, the states, and the FWS must be created.

Although spotted owl recovery would be enhanced by replacing the short-term protection of individual owls with long-term conservation efforts consistent with recovery objectives, such protection efforts will not be initiated unless landowners see that it is to their benefit to participate in protective management.

Section 10 of the Endangered Species Act allows nonfederal landowners to develop habitat conservation plans (HCPs) as a condition for issuance of incidental taking permit. ection 4(d) of the act is an alternative conservation tool, which allows the FWS to promulgate "special rules" for the protection of threatened species. The FWS has indicated it will consider writing such rules if the states or landowners develop conservation or protective management plans. Rules also could provide interim management direction while an HCP is being developed.

In California, several landowners, forestry associations, environmental interests, and scientists currently participate in habitat protective management efforts with the state, FWS, Forest Service, and BLM. A few California companies are working directly with the FWS to develop their own habitat conservation plans that are expected to be consistent with the statewide plan. The statewide HCP is expected to be completed by 1993, at the earliest, underscoring the need to establish and maintain a positive climate for negotiation (see section II.C.).

The real or perceived disincentives to protective management cause delay in implementation of improved protection for the species. With each year of protective management delay, habitat is cut outside take circles, reducing options for recovery. After several years of take circle management, habitat on nonfederal lands may be found only inside those circles.

Expediency of plan development, approval, and implementation may be the most important criterion for successful protective management. Some HCPs have been completed in 6 to 12 months but others have taken substantially longer to complete. Available mechanisms to achieve recovery objectives on nonfederal lands should be streamlined to achieve the same conservation goal in a more efficient and less costly manner.

A process for incorporating implementation tools into protective management.

The following scenario presumes that the FWS finds that the approach identified for nonfederal lands is consistent with the intent of sections 4, 9, and 10 of the Endangered Species Act (i.e., consistent with the conservation of the owl), and that the states indicate their willingness to support the recovery plan and the approach for compliance under the Endangered Species Act on nonfederal lands through appropriate state laws.

1. States and the FWS would develop a detailed implementation strategy for the use of nonregulatory mechanisms, such as land acquisition, to contribute to recovery goals. (see Tools for implementing recovery on nonfederal lands in this section.)

2. The FWS, states, and landowners agree on a regulatory program as follows:

    a. Specific landowner contributions that would allow specified levels of incidental take to occur would be identified and agreements made to implement them.

    b. Means for ensuring and monitoring implementation of the agreements are identified and put in place.

    c. State and/or landowners incorporate 1 and 2 (above) into protective management plans, forming the basis of either a section 10 permit or a section 4(d) rule.

    d. The FWS pursues the appropriate action, including public review, which authorizes incidental take and ensures implementation of the alternative protective management plan. The states may require additional measures above those identified in the recovery plan or under the FWS's take guidelines.

Tools for implementing recovery on nonfederal lands.

The Recovery Team evaluated the availability and effectiveness of several mechanisms for implementation of the recovery objectives for nonfederal land, identified in section III.C.4. These mechanisms are elements of a comprehensive approach to owl conservation. Any one or a combination of these may be acceptable. This list may not be all inclusive; other equally valid ideas may exist. Anticipated implementation of the biological objectives varies by province owing to differences in the proportion of federal ownership, state authorities, and availability of information about spotted owls.

Implementation tools are defined as:

1. *Existing reserves.* State, county, or local parks, known conservation easements, or other areas that have binding, enforceable restrictions on the level of timber harvest and other forest management activities that are likely to alter the amount of suitable owl habitat. Existing reserves must be evaluated on 1) the level of current habitat within them, 2) size, 3) number, 4) spacing, and 5) timing of future habitat achieving owl suitability characteristics.

2. *Private voluntary actions.* Actions that are not required by statute or regulation, but that landowners voluntarily undertake. Actions can include, for example, long-term management plans, commitments to long rotations per uneven-aged management, or easements. Such actions must be evaluated on 1) how binding the actions are over time, 2) effectiveness in providing the conservation measures (number of owls, amount and configuration of habitat) stated in the recovery objective, 3) timing of the contribution of suitable habitat, and 4) how attractive they are to landowners to undertake.

3. *Forest practices statute and regulations.* Statutes and rules enforced by state or local government that require certain practices be used or certain habitat conditions be maintained. Depending on the definition of different types of owl habitat, these requirements can contribute to certain habitat objectives. Statutes and regulations must be evaluated on 1) current requirements for the provision of conservation measures detailed in the recovery objective, 2) whether current state statutes authorize promulgation and enforcement of additional regulations, and 3) ability, ease, and timing requirements of passing new state legislation.

4. *Prohibition on taking.* Refers to the Endangered Species Act prohibition of take of individuals, as implemented and enforced by the FWS. The relative ease of implementing an option will be increased to the extent that protection of individuals (on a case-by-case approach) implements the conservation measures in a recovery objective. The current take prohibition does not provide a long-term contribution to recovery. The success of the prohibition in contributing to recovery is variable, and dependent upon the province and existing conditions within owl home ranges. Application of take prohibition guidelines must be evaluated for consistency of results, fairness, uniformity of enforcement, and adequacy of protection.

5. *Landscape management as a basis for modifying the take prohibition.* Refers to providing suitable habitat adequate to meet the conservation objective, without necessarily focusing on the location of individuals or pairs. Landscape management may provide a basis for allowing an increased level of take. The potential role of landscape management must be assessed relative to the current number of known owl sites contributing to recovery objectives and the current burden of surveys (see Protective Management Guidelines, point #5). The Endangered Species Act provides mechanisms for landscape habitat management, including the habitat conservation plan (HCP) or section 4(d) rules.

6. *Critical habitat.* See description under Federal Implementation in section III.C.

7. *Land exchange.* Exchanging public land (fee title) for state and private lands to secure a particular location and/or management. This tool must be evaluated on 1) the availability of public land of equal value for exchange, 2) the ownership of the public land (federal, state, county), 3) the

authority of the public body to enter into land exchanges, 4) the change in public timber supply as a result of the exchange, 5) effect on local tax base, 6) the willingness of nonfederal landowners to enter into exchanges, and 7) the timing of the exchange.

8. *Purchase.* Purchase of fee title of private or state lands for reasons similar to land exchange. Purchase must be evaluated on 1) the authority of the public sector to purchase private or state land, 2) the availability of resources for public purchase, 3) the willingness of the nonfederal parties to sell, 4) the change in public timber supply as a result of the purchase, 5) effect on local tax base, 6) the timing of the purchase, 7) whether purchase is of both land or timber or whether some harvest rights are retained by seller.

9. *Timber rights trade.* Rather than purchasing or exchanging land, federal and nonfederal parties exchange timber cutting rights without altering land ownership. This should be evaluated in the same way as land purchase or exchange. Legal technicalities may need to be addressed.

10. *Conservation easements, mitigation banks, purchase or transfer of development or harvest rights.* A number of "market-oriented" tools are available for protective management. These tools are characterized by being voluntary, rather than mandatory, and allow all parties involved to base their decisions on the likely costs and benefits they will incur. The availability of these tools increases the options for efficiently meeting conservation goals.

    A conservation easement is dedicated for conservation purposes, such as open space or wildlife habitat. The landowner is compensated for placing land in an easement, often through preferential property tax treatment.

    The feasibility of conservation easements must be evaluated in terms of 1) the availability of suitable areas for easements, 2) the ability to administer the easements, such as the existence of land trusts, and 3) the relative benefits that a landowner could expect from entering into a conservation easement.

    Mitigation banking is an offsite mitigation tool intended to compensate for habitat losses associated with future timber harvesting or other activities. Credits must be established (e.g., acres of owl habitat) prior to timber harvesting. The intent of mitigation banking is to develop a surplus of secured habitat before timber harvesting proceeds in existing suitable habitat to minimize the lag time between losses from timber harvesting and replacement from mitigation. Mitigation banking can consolidate mitigation measures from numerous small habitat losses and provide a larger off-site mitigation area.

    The feasibility of mitigation banks must be evaluated based on 1) the availability of suitable sites for mitigation banks that would not have been protected otherwise, 2) the ability to establish appropriate measure of credits, 3) the institutional ability to administer the banks and monitor their effectiveness.

    Transfer of development or harvest rights is another mechanism to allow higher levels of activity, such as timber harvesting, on location (destination or sink) by transferring unused rights from another location (source), thereby reducing the potential level of activities in the source location. Purchase of such rights can be used to lower the overall potential level of timber harvesting in an area by not transferring them to another location.

The feasibility of transfer or purchase of rights must be evaluated against 1) biological constraints regarding habitat quality, quantity, and location, 2) availability of institutional means to evaluate, monitor, and keep account of the trades, and 3) transactions costs to landowners and administering agencies. Any trades would have to be carefully and conservatively structured owing to the uncertainty about their biological and social and economic effects.

Implementation Scenario

In section III.C.3., the recovery plan assumes that federal agency implementation will occur in phases during the next 5 years. An approach to recovery plan implementation that is feasible and prompt might occur in three broad phases. The first phase, which should take less than 1 year, involves completion of a federal and nonfederal review of its recommendations to determine organization-specific actions needed to achieve consistency; e.g., forest and resource management plan revisions, and to carry out interim management which serves as an appropriate "bridge" to full implementation. The second phase, which likely will require up to 2 years, involves completing these general resource management planning activities, preparing the more specific DCA management plans recommended in the recovery plan, and adopting research and monitoring strategies, and initiating related on-the-ground management actions. The third phase includes further refinements of management activities, including monitoring and research, that characterize full-scale implementation, and the development of information for use in reviewing and, as necessary, revising the recovery plan.

The following outline briefly describes this phased implementation strategy. It lists anticipated activities in each phase of federal action agency (Forest Service, BLM, National Park Service), nonfederal entities, and the FWS. Some of the actions specified in each phase are interdependent, and it is assumed that they may proceed either concurrently or sequentially, as necessary.

Phase 1 (May 1992 - May 1993)

1. Federal action agencies:

   - Review the recovery plan to determine management requirements needed to achieve consistency with recovery plan recommendations and take prohibitions as required by FLPMA, NFMA, NEPA, and any other applicable mandates (e.g., forest plan and regional guide revision or amendment).

   - By January 1993, adopt the recovery plan and implement interim management to assure maximum consistency with recovery plan recommendations pending completion of the above management requirements.

2. States:

   - Review the recovery plan to determine how to implement its recommendations under current authorities and initiate necessary actions (e.g., HCP development), in cooperation with private landowners as appropriate.

   - Assess the feasibility of other actions to promote recovery plan implementation.

3. U.S. Fish and Wildlife Service:

   - Promulgate a critical habitat rule to reflect recovery plan recommendations, and use it in conjunction with the DCA management guidelines as the basis for adverse modification determinations.

- Use the recovery plan's recommendations for the federal matrix lands as the basis for section 7 consultation and consider issuing programmatic "no jeopardy" biological opinions (including incidental take statements) for agency plans that are consistent with those recommendations.

- Establish the coordinating group recommended in the recovery plan to provide implementation advice and assistance.

- Issue guidance to states and private landowners to help them in preparing HCPs.

- Assess the desirability of promulgating a special rule under section 4(d) of the Endangered Species Act.

Phase 2 (May 1993 - May 1995)

1. Federal action agencies:

    - Complete actions needed to assure full adoption of recovery plan recommendations in accordance with their legal mandates.

    - Adopt monitoring and research strategies.

    - Prepare DCA management plans, consult with the FWS, and implement required actions including silvicultural treatments to enhance owl habitat.

2. States:

    - Continue efforts to implement recovery plan recommendations for nonfederal lands, including HCP development.

    - Coordinate with federal agencies and the private sector on monitoring and research efforts.

3. U.S. Fish and Wildlife Service:

    - Consult on DCA plans submitted by action agencies and consider issuing programmatic "no adverse modification" biological opinions to cover future actions carried out consistent with those plans.

    - Provide advice and assistance on all aspects of recovery plan implementation as required, in conjunction with the coordinating group.

    - Assess progress toward recovery plan implementation and provide appropriate recommendations.

    - Complete promulgation of a special rule.

Phase 3 (May 1995 - May 1997)

1. Federal action agencies:

    - Complete planning requirements and be in "full implementation" regarding program operations, as well as monitoring and research.

    - Report on the results of recovery plan implementation during the first 5 years.

2. States:

• Continue to implement the recovery plan's recommendations, especially those designed to provide further incentives for owl and habitat conservation.

3. Fish and Wildlife Service:

• Devote primary efforts to providing advice and assistance on owl recovery, as opposed to regulatory operations, if federal agencies are in the "full implementation" phase.

• With assistance from the coordinating group, provide guidance to federal action agencies, states, and private landowners on the process and information requirements for recovery plan review after its initial implementation phase, so that review can begin promptly in May 1997, and revision completed in a time frame that enables it to serve as a basis for agency decadal planning.

III. C.

4. Recovery Goals and Strategies for Each Province

Overview

Recommendations made in this section are specific to physiographic provinces based on the classification of Franklin and Dyrness (1973) and Bailey (1966)(Figure 2.2.). Physiographic provinces are determined by the geophysical landscape characteristics and climate that influence the vegetation. For practical application in the recovery plan, physiographic provinces were modified based on state boundaries, current spotted owl distributions, and land ownership patterns, all of which influence the potential for management recommendations.

The status of spotted owls in each province and recommendations for recovery are summarized in this section. Recovery goals for each province are based on the status of spotted owls, threats to the population (section II.B.), and the recovery plan objective (section III.A.). These goals are intended to alleviate the primary threats in each province. Recommendations for federal and nonfederal land reflect the obligations of different ownerships under the Endangered Species Act. Indian lands are identified, but presented as neither federal nor nonfederal lands; contributions from Indian lands are described in section II.C.8.

Recovery strategies and recommendations in this section describe areas and actions by land managers that are necessary for spotted owl recovery. These include the DCAs and matrix management areas on federal land, and areas of special management emphasis on nonfederal lands.

Federal lands

The primary recovery strategy on federal lands is the establishment and appropriate management of DCAs, as described in section III.C.2., including designation of DCAs as critical habitat. DCAs are illustrated on maps provided with the draft recovery plan (Maps 1 through 3). Recommended DCA boundaries are delineated, but it is anticipated that during the response period to the draft, local land managers will suggest boundary changes to improve owl habitat management. Such proposed changes will be evaluated by the Recovery Team and incorporated into the final recovery plan, as appropriate.

In the province narratives, category 1 and 2 DCAs are listed, including approximate acreages and owl numbers. Detailed information on individual DCAs is in Appendix J.

Federal matrix lands connecting the DCAs will be managed for dispersal habitat and also include areas that require management for reserved pair areas, managed pair areas, and residual habitat areas (see section III.C.2. for a description of matrix prescriptions).

Nonfederal lands

Most of the spotted owl recovery effort will be on federal lands. However, where recovery cannot be met solely on federal lands, recommendations are made for nonfederal lands. These recommendations include the following terms:

Supplemental pair areas - Habitat delineated for pairs or territorial single spotted owls on nonfederal lands. Such habitat is managed or reserved, depending on agreements made. These areas are intended to supplement population deficiencies in the federal DCA network. The size of these areas will vary by province.

Nonfederal clusters - Habitat provided to support a localized cluster of supplemental spotted owl pair areas intended to contribute to owl population needs as described in the province narratives.

Protective management - Measures taken by nonfederal entities to conserve spotted owls and/or their habitat; measures may include participation in conservation planning (as defined in Endangered Species Act section 10) or other actions that benefit owls; entities may be states, private landowners, Indian tribes, or others.

The biological recommendations for nonfederal lands take several forms. The status of local owl populations and habitat conditions determines whether recommendations are made for specific areas, and the form of those recommendations. The biological principles underlying these recommendations are discussed in section III.B.2. Specific recommendations for each province are discussed in the province narratives. They generally can be described in one of the following ways.

1. Nonfederal lands within DCAs - Provide adequate nesting, roosting, and foraging habitat, in conjunction with federal lands, to achieve the DCAs' target for owl numbers and demographic stability. This could apply to checkerboard and non-checkerboard ownership patterns. It may include the provision of supplemental pair areas. This habitat may be either managed or reserved from timber harvest, depending on the protective management agreements for the area.

2. Nonfederal population clusters - Establishing large clusters of owls is recommended in some areas where federal lands cannot support the recovery objective without contribution from other ownerships (e.g., southwest Washington, northeast Oregon, and coastal California). This would require that habitat be provided for a cluster of breeding owl pairs with contiguous or nearly contiguous home ranges, and for floater owls and dispersing juveniles. Clusters would include 15 or more owl pairs to provide at least short-term population stability. The size of an area provided for a cluster will depend on the current suitability and natural potential of habitat, the possibility of natural disturbance, and the type and level of forest management proposed within the area. Clusters provide the opportunity to explore and test hypotheses about owl response to forest management that may not be tested within the federal DCA network. Generally, a large cluster of owl pairs would require 30,000 to 100,000 acres of habitat managed for owls.

   As with supplemental pair areas, habitat for a population cluster may be either managed or reserved from timber harvest, depending on the protective management agreements for the area.

   In areas of low owl density, where goals for large clusters cannot be met fully, this recommendation may be modified to provide for smaller owl clusters. Small clusters have a lower assurance of population stability than large clusters.

   Alternatively, in some areas a recommendation is made for supplemental pair areas distributed across the landscape at a density lower than that described for clusters. This may provide for a self-sustaining local population but with considerably less long-term population stability than clusters.

3. Within dispersal distance of deficient DCAs - Where needed to meet the DCAs' target for owl numbers and demographic stability, provide supplemental pair areas. These areas are included in the areas of special management emphasis.

4. Nonfederal matrix management - In some areas, a recommendation is made to provide for successful dispersal of owls across a relatively short distance (less than 12 miles) to provide for interaction of owls among pair areas, DCAs, or nonfederal clusters. This normally would require foraging, roosting, and dispersal habitat distributed through the landscape, or possibly arranged in a corridor. However, nesting habitat would enhance dispersal opportunities. Nonfederal dispersal habitat will not necessarily follow the 50-11-40 rule used for federal dispersal habitat, but would be based on the long-term commitments that had been entered for the area.

Since the listing of northern spotted owls as a threatened species, protection measures have been established to comply with Endangered Species Act requirements on nonfederal lands (prohibition of take), through consultation with the FWS and through various state forest practices acts. These measures are contributing to the accomplishment of biological goals for the provinces. However, accomplishing recovery goals described in each province narrative may require a combination of existing measures and other actions that would be determined through the protective management process.

A result of the protective management process will be a further refinement of areas where recovery contributions are required. The potential for implementation of these recommendations for nonfederal lands is discussed in the implementation section for each of the states (section III.C.2.). That section also discusses the processes that would be followed to develop more specific management of owls and owl habitat on nonfederal lands. Generally, those processes would consist of states and private landowners working with the FWS to develop mechanisms under state law that would provide for owl protection while concurrently modifying take prohibition standards. Another possible approach would be to follow conservation planning under section 10 of the Endangered Species Act.

When all goals for a province have been established for federal and nonfederal land and mechanisms are being put in place to accomplish those goals, a schedule should be developed to modify take prohibitions for areas where no long-term contribution to recovery of spotted owls is required. If take prohibitions were removed, the recommendation would be to protect the nest site during the breeding season. While only areas of special management emphasis are discussed, the spotted owls and habitat outside of these areas make contributions to current population maintenance. Until long-term recovery commitments are in place on nonfederal lands, the contribution of these owls and their habitat is important for short-term maintenance of the owl population.

Olympic Peninsula Province

Province description

The Olympic Peninsula is a relatively isolated province in northwest Washington, bordered on three sides by bodies of water. The central portion of the peninsula is a mountain range with high elevation ridges radiating from the central area throughout Olympic National Park and Olympic National Forest. Currently, spotted owl habitat is located generally in mid-elevational forests along major river systems draining the mountains.

Numbers of owls currently are estimated between 175 and 200 pairs (111 pairs are known at this time). Productivity of the population appeared to be extremely poor in the mid-1980s, but was good in the 3 years prior to 1991. Productivity in 1991 was very poor (Forsman, pers. comm.). Reasons for these fluctuations and whether there is a pattern to the fluctuations are unknown. Owls generally occur on federal land at mid-elevations, but a smaller number of owls resides on primarily nonfederal lands in lower elevational habitats in the western portion of the peninsula.

Threats to the Olympic Peninsula spotted owl population include relatively low numbers of owls, the significant risk of large-scale disturbances (wind and fire), and stochastic patterns of productivity. There is a significant threat to habitat from large-scale windstorms in the western portion of the peninsula (Appendix F), and the threat of wildfire in the east portion. These threats to habitat create a risk to owl population stability. The recovery strategy is to alleviate these long-term threats to the population by protecting a large proportion of existing owl pairs and reestablishing connections to spotted owl populations in the Washington Cascades and northwestern Oregon. The entire Olympic Peninsula is considered an area of special management emphasis.

The major Indian reservations in this province are the Makah and Quinault. The Makah Reservation is not known to include spotted owls or their habitat. The contributions of the Quinault Nation are described in section II.B.

Biological goals and implementation on federal lands

One large DCA is recommended on federal lands in the interior Olympic Peninsula. This includes all suitable habitat in Olympic National Park and a large proportion of Olympic National Forest adjacent to the park. This DCA, WD-36, has four additional parcels which are separated from the body of the DCA. Another recommended DCA (WD-45) is the Olympic National Park coastal strip, encompassing a relatively narrow strip of land from Lake Ozette south to the Queets River.

Three small parcels of WD-36 are recommended in the Soleduck Ranger District. These are important a) to help maintain distribution in the western portion of the peninsula, b) to provide demographic support to the large interior portion of WD-36 until the owl population meets future expected numbers, and c) in conjunction with nonfederal lands, to support habitat connectivity with Olympic National Park's coastal strip.

Also, a parcel of WD-36 is recommended in the southern portion of the Hood Canal Ranger District. This habitat parcel should be maintained to serve as a nesting area for a future small cluster of spotted owls. A cluster of owls may be needed in this area to provide for future interchange of owls between the Olympic Peninsula and the western Washington lowlands province.

The large interior DCA (WD-36) is recommended for several reasons specific to the peninsula (section II.B). Historical timber harvest in Olympic National Forest has occurred in lower elevations, removing habitat and restricting the remaining owls in the national forest to a relatively narrow band encircling the periphery of Olympic National Park. When the remaining national forest habitat is combined with the habitat in Olympic National Park, it results in a ring of habitat surrounding the high elevation area at the center of the park. The high elevation interior area does not contain habitat suitable for owls and probably restricts dispersal.

Because of this unusual configuration of habitat, a single large DCA is recommended to help ensure connectivity within the population. A series of smaller

DCAs, separated by dispersal habitat, would provide a lower probability of successful dispersal, given the geography of the peninsula. In addition, the large DCA will protect habitat for enough owl pairs to reduce the risk from stochastic environmental or demographic events. This is an extremely important consideration on the Olympic Peninsula because the spotted owl population here virtually is isolated from the remainder of the owl's range (USDA 1988; Thomas et al. 1990).

There are 89 known pairs of owls located within federal lands in the DCAs. These represent 97 percent of all owl pairs located on federal lands in the province (Table 3.3 and Figure 3.7). The DCAs contain 70 percent of the nesting, roosting, and foraging habitat identified on federal lands in the province (Table 3.4 and Figure 3.8).

Table 3.3. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the Olympic Peninsula province. (More detailed information, including projected owl pairs on nonfederal land, is in Appendix J, Table J.1.)

DCA Ident. Number	Acreage: Total	Acreage: Percent Federal Land[1]	Acreage: NRF Habitat Federal[2]	Owl Pairs: Known Owls[3] Federal	Owl Pairs: Known Owls[3] Nonfed	Owl Pairs: Current Projected Federal[4]	Owl Pairs: Future Projected Federal[5]
WD-36	847,086	97	446,519	84	2	124	193
WD-45	35,439	100	-	5	0	8	8
Totals:	**882,525**	**97**		**89**	**2**	**132**	**201**
Total for all lands in province:			**636,839**	**92**	**19**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.4. Summary comments on the designated conservation area (DCA) network in the Olympic Peninsula province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
WD-36	A DCA is recommended within and around Olympic National Park to increase habitat connectivity among major drainages, to include habitat at a variety of elevations, and to support a potentially isolated population. It is delineated as one large area, plus four small satellite areas.
WD-45	This DCA lies in the coastal strip of Olympic National Park. It is expected to support eight spotted owl pairs.

Biological goals and implementation on nonfederal lands

The overall goal for nonfederal lands on the Olympic Peninsula is to provide demographic support to the Olympic Peninsula owl population. Specific province objectives are to protect individual pairs and to increase habitat connectivity between Olympic National Park's coastal strip and interior federal land.

Given the current distribution of remaining owls and habitat there are several possibilities to meet recovery needs. One option for providing demographic support is through protection of spotted owls where they currently occur throughout the peninsula, since remaining spotted owl habitat on nonfederal land is located close to federal land. Habitat to support small clusters of three to four owls pairs in conjunction with protective measures on federal land would be desirable to meet the province objectives.

The recommended option is to provide demographic support and increased habitat connectivity in the western portion of the Olympic Peninsula, from Lake Ozette south to the Queets River and from the coast east to federal ownership. Currently, there are approximately 35 known spotted owl activity centers located on both federal and nonfederal land in the area. Since individual owl activity centers overlap several ownerships, protective management on nonfederal lands should be integrated and coordinated with federal lands.

Long-term protective measures that increase connectivity between Olympic National Park's coastal strip and the interior peninsula should be planned to provide maximum overlap with needs of other vulnerable species (e.g., salmon, marbled murrelet, fisher, northern goshawk). Planning should consider the need for contiguous habitat between Olympic National Park's coastal strip and the interior peninsula, as this would provide benefits to spotted owls and may be required for other species associated with late successional forests. Measures to increase spotted owl population connectivity are recommended in one or two locations between interior federal ownership and Olympic National Park's coastal strip. Currently, several areas are capable of reestablishing this connectivity in the foreseeable future. These areas of contiguous habitat should be at least 1 mile wide to provide for breeding pairs of spotted owls.

Long-term provisions for 20 to 30 pairs of spotted owls on all ownerships in this area should meet province objectives for demographic support by a) maintaining owls in the western portion of the province in a range of elevational and ecological conditions and b) increasing the likelihood of successful dispersal between the coastal strip and the interior. Small clusters of owl pairs are preferred to individual owl pair protection and, to the extent feasible and practical, should be considered. Individual owl pairs should be protected with supplemental pair areas. The amount of owl habitat should be equal to the median amount learned from research studies in the province. Owl habitat should be provided to the maximum extent possible within an area equal to the median home range size for the province.

The establishment of areas of habitat connectivity, pair protection, and/or small clusters dramatically would enhance dispersal capability in this area. The need for additional areas of dispersal habitat should be evaluated when these areas have been designated.

Additional information would be beneficial in planning nonfederal contributions on the Olympic Peninsula. The spotted owl life history simulation model developed by Forest Service researchers (discussed in Appendix A) and demographic information from on-going research could be a valuable tool in plan-

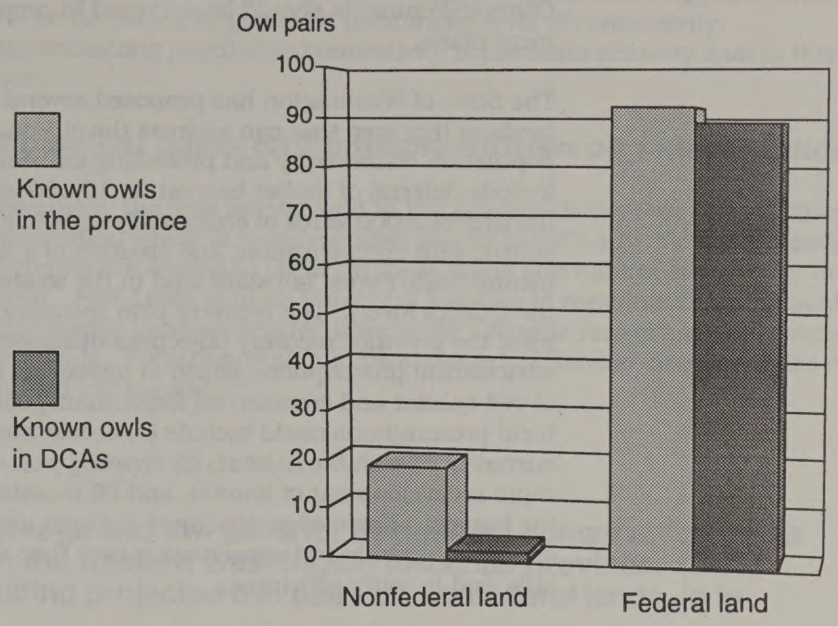


Figure 3.7. Known owl pairs in the Olympic Peninsula province and in DCAs within the province.

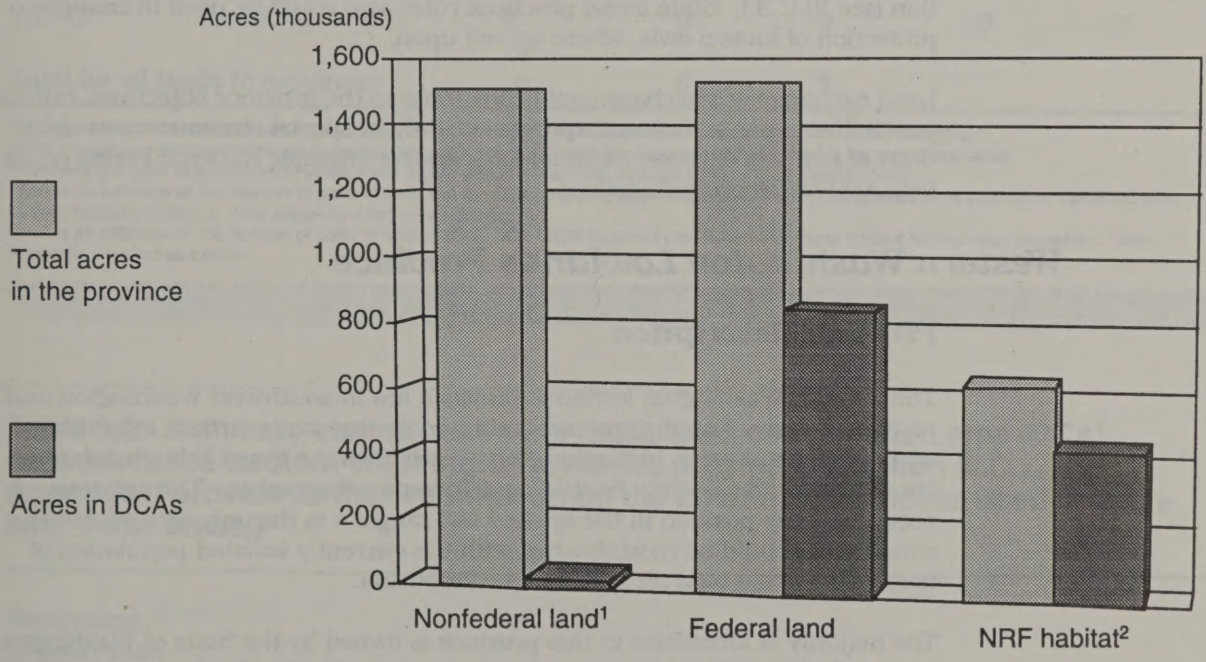


Figure 3.8. Acres in the Olympic Peninsula province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

ning. Also, several unsurveyed areas of potential habitat remaining on the Olympic Peninsula should be surveyed in preparation of protective management plans.

The State of Washington has proposed several voluntary actions for state trust lands in this area that can address the objectives of improving spotted owl population connectivity and protecting individual owl pairs. These actions include deferral of timber harvest on 15,000 acres of spotted owl habitat; transfer of 3,000 acres of ecologically sensitive land from trust to conservation status, with compensation; and creation of a 260,000-acre Olympic Experimental State Forest (all state land in the western half of the province, north of the Queets River). The recovery plan recommends that the experimental forest meet the province recovery objectives discussed earlier and develop and test silvicultural prescriptions aimed at improving compatibility between protection of owl habitat and commercial forest management. Objectives of the silvicultural prescriptions could include (1) accelerating habitat development of currently unsuitable habitat, (2) creating post-harvest conditions conducive to rapid redevelopment of habitat, and (3) maintaining habitat suitability following harvest. Knowledge developed through work on the experimental forest could be useful to owl conservation over time throughout the Olympic Peninsula and in other provinces.

Prohibitions on take also are contributing to the province recovery objectives by protecting known owl activity centers. However, protective management and conservation planning, as described in section III.C.3., could lead to more efficient conservation actions and increase the feasibility of meeting the recovery objectives for the province. For some private landowners, it also may be possible to negotiate contributions of land in trade for relief from take prohibition (see III.C.3.). State forest practices rules also could be used to ensure protection of known owls, where agreed upon.

Land exchange or purchase could contribute to the province objectives, but the prohibitive expense makes it appropriate only in special circumstances. Additions of lands to Olympic National Park and/or Olympic National Forest could help achieve recovery objectives.

Western Washington Lowlands Province

Province description

The western Washington lowlands province lies in southwest Washington and consists largely of nonfederal ownership, including major urban, industrial, and agricultural areas in Washington. It includes the Puget Trough, which encompasses the Everett, Seattle, and Tacoma urban areas. The province occupies a key position in the spotted owl range; it is the only area where connectivity could be reestablished with the currently isolated population of northern spotted owls on the Olympic Peninsula.

The majority of forestland in this province is owned by the State of Washington or large industrial timber corporations. As a result of timber harvest, northern spotted owls have been virtually eliminated from the province; only four activity centers are known in the province. Major threats to the remaining owl territories include low habitat quantity, poor distribution of habitat and owls, and local population isolation.

A contributing concern in this province is the risk to the owl population in the adjacent Olympic Peninsula. To alleviate this threat of population isolation, population connectivity should be reestablished across the Washington lowlands province to both the Washington Cascades and northwestern Oregon.

Because of the distances involved, the presence of breeding population clusters will be necessary to provide a meaningful level of connectivity. Reestablishing population connectivity is the main recovery goal in this province.

Biological goals and implementation on federal lands

Essentially the only federal land in the province is the Fort Lewis Military Reservation which is recommended as a DCA (WD-43). No spotted owls currently are known to occur on these lands and habitat is generally in young forest. Fort Lewis is in an important location to reestablish demographic interchange between spotted owls in the Cascade Range and the Olympic Peninsula. Forestlands should be managed to develop characteristics of spotted owl habitat.

Table 3.5. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the western Washington lowlands province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J.2.)

DCA Ident. Number	Acreage: Total	Acreage: Percent Federal Land[1]	Acreage: NRF Habitat Federal[2]	Owl Pairs: Known Owls[3] Federal	Owl Pairs: Known Owls[3] Nonfed	Owl Pairs: Current Projected Federal[4]	Owl Pairs: Future Projected Federal[5]
WD-43	81,590	97	0	0	0	0	21
Total for all lands in province:			**0**	**0**	**3**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.6. Summary comments on the designated conservation area (DCA) network in the western Washington lowlands province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
WD-43	This DCA is located entirely on the Fort Lewis Military Reservation. Forests are generally less than 70 years old. It will improve connectivity with the Washington Cascades and the Olympic Peninsula populations. The area has the future habitat capability to support 21 pairs of owls.

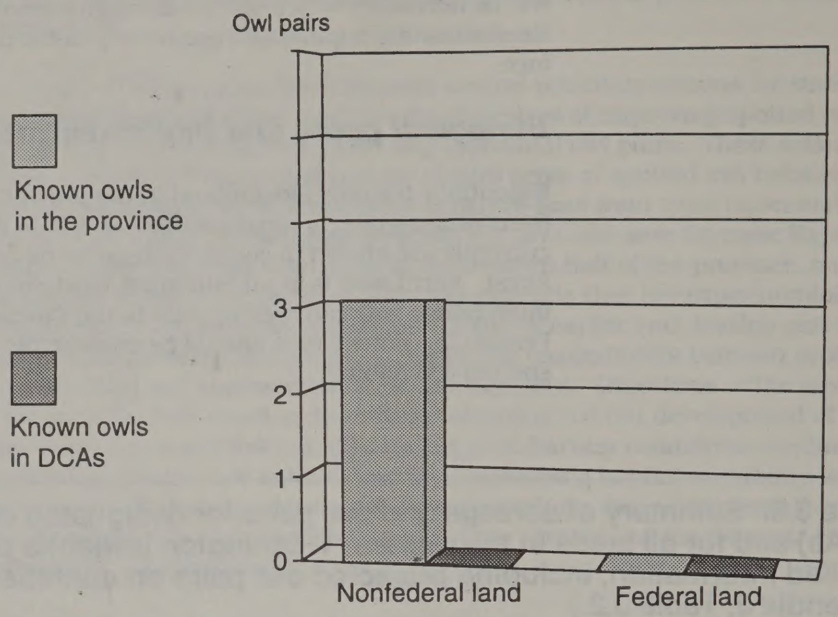


Figure 3.9. Known owl pairs in the western Washington lowlands province, and in DCAs within the province.

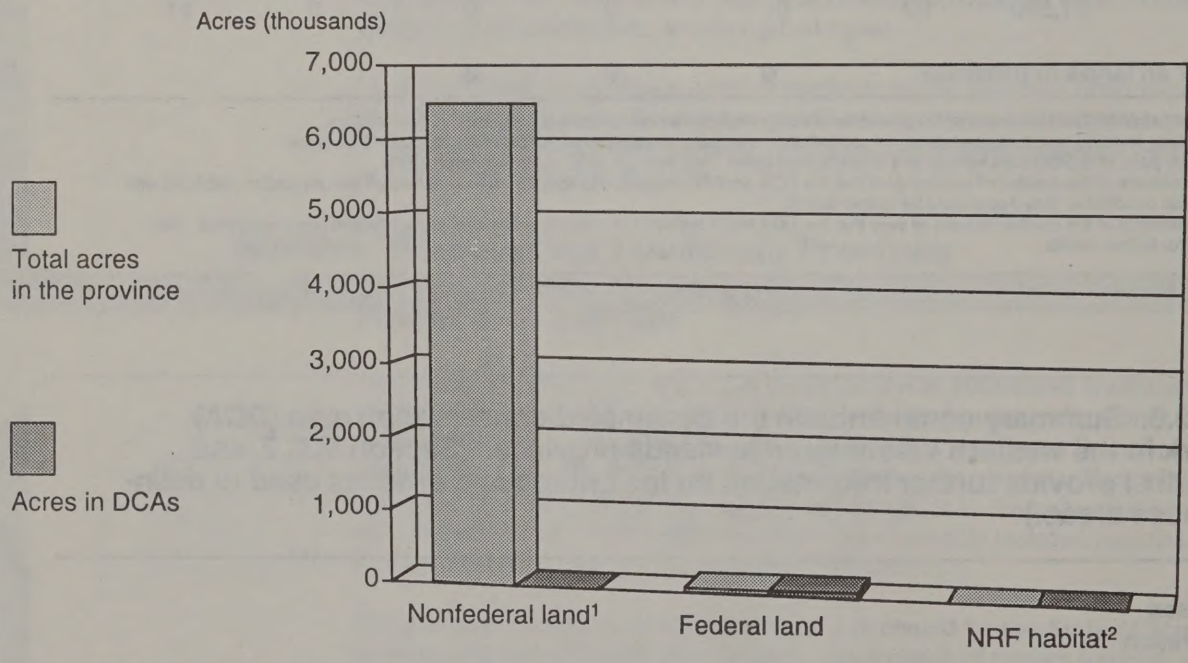


Figure 3.10. Acres in the western Washington lowlands province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

Biological goals and implementation on nonfederal land

The low habitat quantity and poor habitat distribution requires that the entire province be identified as an area of special management emphasis. However, within the province there are areas which should receive focused attention to be most effective in achieving province objectivies. Reestablishing population connectivity is the main recovery objective in this province. To achieve this, both owl clusters and dispersal habitat are recommended. In the future, nonfederal lands should be managed to provide clusters of supplemental pair areas to contribute to the objective. Such clusters should be:

1) designed for a minimum of 15 future spotted owl pairs,
2) spaced a maximum of 12 miles apart,
3) dispersal habitat should be provided between clusters with dispersal areas as continuous as feasible.

There are several reasons that make the objective difficult to achieve. Since there are few existing owl sites in this province, prohibition on take or negotiating conservation in trade for relief from take prohibition within the province are not feasible means of contributing to recovery. A few relatively small preserved areas exist in southwest Washington, such as the State Natural Heritage Program lands, but these are not adequately sized to support clusters of breeding pairs, or located to serve well as dispersal habitat. Provision of breeding habitat independent of known owl sites cannot be required under current state forest practices law.

To establish breeding clusters in this province, land acquisition appears to be the only effective strategy. This is because there are limited opportunities for federal/nonfederal land exchanges in this province. But purchase of land and timber sufficient to meet the objective would be prohibitively expensive (more than $2 billion).

To reduce this cost, purchase of bare land, or land with some timber harvest rights reserved to the seller, may be feasible (possibly reducing costs to $150 million). This approach would delay achievement of the recovery objective by several decades because the forest would have to regrow into owl habitat. However, the continuing threat to the owl population on the Olympic Peninsula, necessitating reestablishment of connectivity, is anticipated over many decades. Even at the lower cost, funding for this approach may be available only over a number of years, and would be considered along with acquisitions to meet recovery objectives for other provinces in Washington.

To answer the need for dispersal habitat, the only effective mechanism appears to be a combination of incentives for landowners and forest practices regulations. New forest practices regulations would have to be developed, and dispersal habitat would have to be well defined. Achievement of the dispersal objective probably is feasible, but would contribute to recovery only if applied in combination with successful establishment of breeding clusters.

The following recommendations are provided for recovery planning in the western Washington lowlands province:

- Continue surveys of potential owl habitat.
- Continue protection of remaining northern spotted owls. The owls should be protected with supplemental pair areas. These areas should be at least as large as the median home range size for pairs in the neighboring Olympic Peninsula province (size information from the Olympic Peninsula province is being used because studies have not been conducted in this province to provide a size estimate). It is recommended that delineation and management of these areas follow guidelines similar to those for reserved pair areas or managed pair areas on federal lands.

- Initiate long-range planning efforts to develop conservation measures for the northern spotted owl.
- Consider the needs of other species in designs for clusters.

Western Washington Cascades Province

Province description

The western Washington Cascades province lies along the western slope of the Cascade Range, from the Columbia River to the Canadian border. Approximately 197 spotted owl activity centers, including 166 confirmed pairs, occur in the province. Of these, 179 activity centers and 150 pairs are on federal land. Significant topographic differences occur between the northern and southern portions of the province. The northern area is dominated by high elevation mountains and ridges unsuitable for spotted owls, restricting the suitable spotted owl habitat to lower elevations. The southern portion is much less dominated by mountainous areas, and spotted owl habitat is potentially more continuous. However, it is still highly fragmented by past timber harvest.

Threats to spotted owls in the province include low rates of reproduction in the northern portion and loss of habitat throughout the province. During the past 20 years the checkerboard lands in the Interstate 90 corridor and the Mineral Block in the Gifford Pinchot National Forest have been heavily harvested. (The Mineral Block is a disjunct portion of the forest north of Highway 12 and west of Highway 17). These lands currently support low densities of spotted owls.

Five areas of special management emphasis have been identified and these are reflected in the nonfederal province objectives and recommendations.

Northern half of the province (north of Interstate 90). Habitat in this area is naturally fragmented because of the mountainous terrain, and the fragmentation has been worsened by timber harvest. Spotted owls and their habitat are now poorly distributed in this area. No large clusters of owls currently occur here.

Interstate 90 corridor. Timber harvest in this area of checkerboard ownership has resulted in limited nesting, roosting, and foraging habitat. Low amounts and poor distribution of habitat in this area are serious concerns because they limit opportunities for dispersal between the north and south halves of the western Washington Cascades and between the western and eastern Washington Cascades through the area of Snoqualmie pass.

The Columbia Gorge. Spotted owl populations in Oregon and Washington are separated by the Columbia River. The historic and current levels of interactions between populations in the two states are unknown, but there has been a significant reduction in habitat in the Gorge due to both timber harvest and urban development.

The Mineral Block. This area is key to the potential for population connectivity between the western Washington Cascades and the Olympic Peninsula. Habitat and owls in this area are limited by the pattern of timber harvest within checkerboard ownership.

Siouxon Creek. This area is located southwest of the Mt. St. Helens National Volcanic Monument. It provides opportunities to manage for owls in lower elevation habitat on the west side of the Cascades, with potential benefits to population connectivity with the Oregon Cascades and the Olympic Peninsula.

Table 3.7. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the western Washington Cascades province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J.3.)

DCA Ident. Number	Acreage			Owl Pairs			
	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
WD-1	153,631	96	92,280	15	1	23	41
WD-2	111,756	100	83,240	14	0	25	31
WD-2N	52,239	92	33,560	8	0	10	12
WD-2W	16,781	96	10,040	3	0	3	2
WD-3	175,414	98	103,295	16	0	23	45
WD-4	133,304	82	56,001	10	2	14	30
WD-8	87,945	96	44,120	6	0	11	24
WD-9	104,211	98	58,248	10	0	14	28
WD-10	54,737	59	14,880	4	0	5	8
WD-11	12,535	99	4,830	1	0	1	1
WD-17	29,740	53	7,400	1	0	3	2
WD-18	27,331	92	11,880	2	0	3	5
WD-19	38,404	92	19,560	1	0	7	9
WD-19W	13,517	91	6,840	2	0	3	3
WD-25	31,273	58	17,320	3	0	5	8
WD-26	23,081	53	12,640	3	0	4	5
WD-26W	14,310	100	8,720	2	0	3	3
WD-27	33,360	98	16,760	4	0	5	8
WD-27S	9,677	96	6,480	1	0	2	2
WD-28	76,925	100	51,360	6	0	14	20
WD-29	26,414	100	18,840	2	0	5	5
WD-30	14,424	100	9,520	4	0	4	3
WD-31	27,386	100	19,423	1	0	5	6
WD-32	37,995	99	19,077	2	0	4	9
WD-34	87,698	100	27,912	0	0	7	10
WD-35	14,448	100	5,435	0	0	2	2
Totals:	**1,408,536**	**94**	**759,661**	**121**	**3**	**205**	**322**
Totals for all lands in province:			**1,431,104**	**150**	**16**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Biological goals and implementation on federal lands

The recovery plan recommends that 26 DCAs be delineated in the province (Tables 3.7 and 3.8). Seven of these meet the criteria for category 1 areas. The DCAs vary in size from 9,600 to 175,000 acres, and 121 pairs of spotted owls have been confirmed on federal lands within their boundaries. This represents about 80 percent of all pairs located on federal lands within the province (Figure 3.11). The DCAs also contain approximately 53 percent of the nesting, roosting, and foraging habitat located on federal land in the province (Figure 3.12).

Table 3.8. Summary comments on the designated conservation area (DCA) network in the western Washington Cascades province. (Section III.C.2.a. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
WD-1, WD-2, WD-3	These are category 1 DCAs. They currently contain sufficient habitat and owl numbers to function as large clusters of interactive owl pairs.
WD-4, WD-8, WD-9, and WD-28	These also are cateogry 1 DCAs. However, they are currently estmated to contain fewer than 20 pairs of owls, each with potential to increase to 20 pairs.
WD-2N, WD-2W, WD-10, WD-11, WD-17, WD-17 through WD-19, WD-19W, WD-25, WD-26, WD-26W, WD-27, WD-27S, WD-29 through WD-32, WD-34, and WD-35	These smaller, multipair areas were delineated in this area to address local demographic, distribution, and linkage concerns. Because of natural habitat limitations and low population densities, they can only potentially support 2 to 19 pairs of owls.

Federal matrix forests will be managed under prescription A (section III.C.2). n addition, four areas have been identified where the establishment of reserved pair areas is needed to compensate for deficiencies in the DCA network. Ten reserved pair areas are needed in the Interstate 90 corridor area north of Mt. Rainier (between DCAs WD-4 and WD-17); eight are needed between DCAs WD-25 and WD-19; and four are recommended north of Darrington (among DCAs WD-9, WD-28 and WD-30).

Biological goals and implementation on nonfederal lands

Specific recommendations for nonfederal contributions are described in the following sections for each of the areas of special management emphasis.

Northern half of the province (north of Interstate 90). The primary recommendation for nonfederal land in this area is to provide dispersal habitat between WD-8 and DCAs to the north, east, and south. Such habitat should provide dispersal for the maximum number of juvenile owls dispersing from adjacent DCAs. Protective management could contribute to the objective, as could land exchange. If new state forest practices regulations were developed, and dispersal habitat was well defined, such regulations also could contribute to this objective.

Interstate 90 corridor. There are several recommendations for nonfederal contributions to recovery in this area. The first is to provide for nesting, roosting, and foraging habitat within or directly adjacent to DCAs with checkerboard ownership. These are WD-4 and WD-17. The second recommendation is to provide nesting, roosting, and foraging habitat to help support the reserved pair areas that will be established on federal land in the checkerboard ownership between these DCAs. Contributions

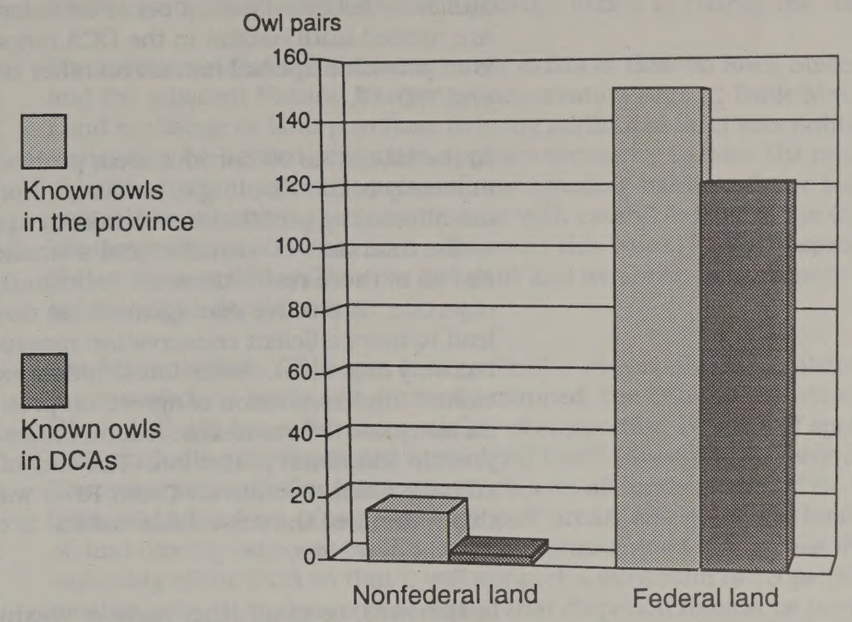


Figure 3.11. Known owl pairs in the western Washington Cascades province and in DCAs within the province.

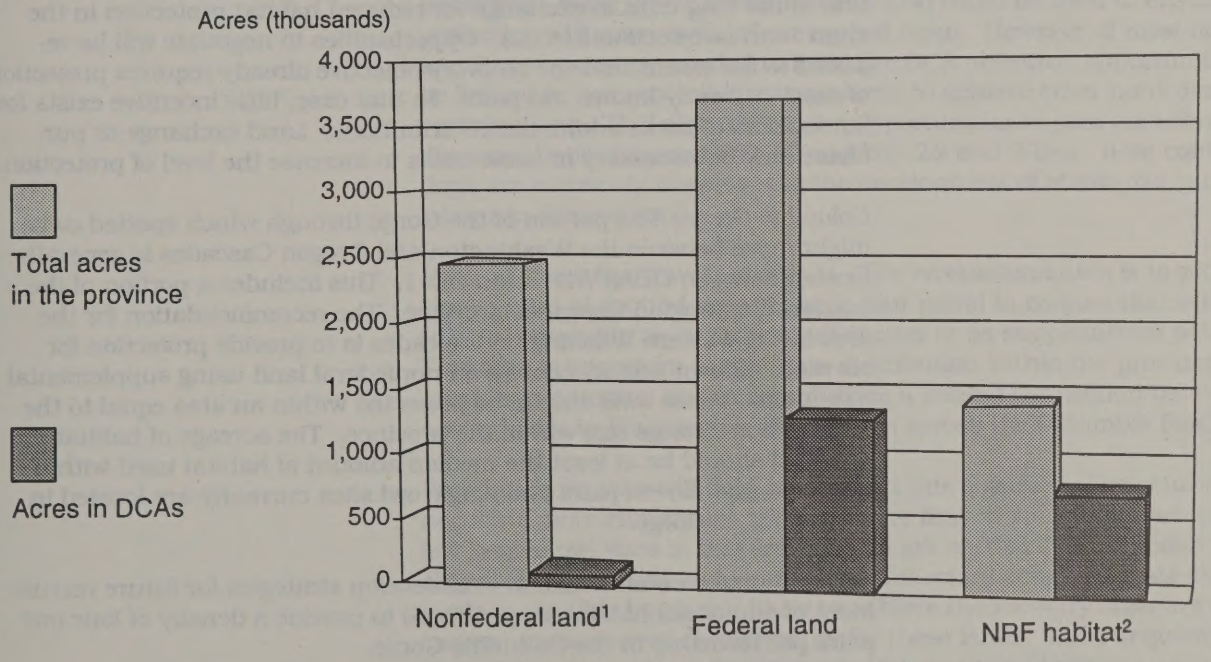


Figure 3.12. Acres in the western Washington Cascades province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

from nonfederal lands are needed to support these 10 sites because sufficient habitat does not occur on federal lands. These contributions are needed until habitat in the DCA recovers. The final recommendation is to provide dispersal habitat on other nonfederal lands between WD-4 and WD-17.

In the Interstate 90 corridor area, prohibition of take on nonfederal lands currently is contributing to recovery. Nonfederal landowners currently are affected by prohibitions on take at approximately 20 owl sites in DCAs in the Interstate 90 corridor, and a smaller number of sites to the north. Not all of these restrictions are contributing to the identified recovery objective. Protective management, as described in section III.C.3., could lead to more efficient conservation measures and improve achievement of recovery objectives. State forest practices rules also could be used to ensure implementation of agreed on protection of known owls. If there is an adequate federal nexus, federal critical habitat designation could provide additional protection. The City of Seattle currently is protecting suitable habitat within its Cedar River watershed (near WD-17). Within this watershed the unsuitable habitat is expected to develop into suitable habitat over time.

In this area, as in all other parts of Washington, known owl pairs currently are partially protected through federal prohibition on take. However, protection is limited to 40 percent of suitable habitat within a 1.8-mile radius of the site center. Additional habitat protection may be needed to ensure long term survival of the pair. Additional protected acreage could be negotiated in exchange for relief from take prohibition on other owls, or a larger area could be managed actively to provide protection in the long term in exchange for reduced habitat protection in the short term (see section III.C.3.). Opportunities to negotiate will be reduced to the extent that the recovery objective already requires protection of most currently known owl pairs. In that case, little incentive exists for landowners to make additional contributions. Land exchange or purchase may be necessary in some cases to increase the level of protection.

Columbia Gorge. The portion of the Gorge through which spotted owls might move between the Washington and Oregon Cascades is generally located between DCAs WD-1 and OD-1. This includes a portion of the eastern Washington Cascades province. The recommendation for the area in the western Washington Cascades is to provide protection for currently known activity centers on nonfederal land using supplemental pair areas. These owls should be protected within an area equal to the median home range size within the province. The acreage of habitat provided should be at least the median amount of habitat used within home ranges. Seven pairs and single owl sites currently are located in the Columbia Gorge.

An additional recommendation is to develop strategies for future recruitment of additional habitat (Appendix G) to provide a density of four owl pairs per township in the Columbia Gorge.

Current prohibitions on take are contributing to the accomplishment of recovery objectives in the Gorge. However, there is little opportunity to negotiate additional landowner contribution in exchange for relief from take prohibition because there are only a small number of known owl sites; most are clustered near the national forest boundary; and most are needed to meet the objective for pairs in the area. State forest practices regulations can help ensure protection of known owls, and, if new regulations were developed, could provide dispersal habitat among pairs.

However, state regulatory protection of breeding habitat independent of known pairs likely would require legislative action to change the statute.

Some state-protected habitat currently exists at Beacon Rock State Park and the adjacent Natural Resource Conservation Area at Table Mountain. Land exchange or land purchase to bring additional land into public ownership for habitat protection appears necessary to meet the recovery objective to establish large areas of new breeding habitat. Some land acquisition is occurring in conjunction with establishment of the Columbia Gorge National Scenic Area. However, this would be very expensive ($10 million to $20 million per owl pair) and would be feasible only with substantial federal funding.

The Mineral Block. This area is of particular importance for contributions from nonfederal lands. As currently mapped, the DCA on the Mineral Block (WD-10) has a future capability of supporting 14 pairs of spotted owls, including checkerboard nonfederal lands (Appendix J, Table J.3.). There are presently five known territories on all lands in the DCA. Contributions, in the form of supplemental pair areas, on nonfederal land inside of, and directly adjacent to, WD-10 are recommended to increase the capability of the DCA so that it will support a minimum of 15 pairs of spotted owls. It is also recommended that dispersal habitat be provided on nonfederal land between DCA WD-10 and DCAs W-2N and W-3.

Within WD-10, prohibitions on take currently are contributing to the province objective of supplementing the DCA. Approximately 10 known owl activity centers occur in and near this DCA. Protective management, as described in section III.C.3., could improve achievement of recovery objectives. State forest practices rules also could be used to ensure protection of known owls, where agreed upon. However, if most or all known owl pairs are needed to meet the DCA objective, opportunities will be limited to use protective management to achieve other nonfederal contributions. This also will reduce opportunities to gain contributions of dispersal habitat among WD-10 and WD-2N and WD-3. hese contributions are extremely important to the development of stable owl subpopulations in the province.

Siouxon Creek (northwest of WD-1). The recommendation is to provide a small group of spotted owls (three to four pairs) in conjunction with federal ownership as either a small cluster or as supplemental pair areas. This area is important to maintain distribution within the province and provides a potential link in establishing a second connection between spotted owls in Washington and Oregon across the Columbia River.

Prohibition on take will help accomplish this objective. Opportunities to negotiate more efficient contributions are limited since there are only a few known owl sites in this area and all are needed to accomplish the objective of providing a cluster. Some voluntary action on state-owned lands is possible but is not likely to achieve the recovery objective given current management requirements for these lands. Land acquisition through purchase or exchange is possible but would require up to $100 million. Less-than-fee acquisitions may have the potential to contribute to the recovery objective in this area. Achievement of the objective in the near term is feasible to a degree.

Eastern Washington Cascades Province

Province description

The province is located on the east slope of the Cascade Range in Washington, from the Columbia River to the Canadian border. Approximately 162 northern spotted owl activity centers have been found in the province; most are on federal land in the central and southern portion of the province. In the northern portion of the province, high mountains create naturally fragmented habitat with low potential for development of large clusters of spotted owls. In the southern portion of the province, the highest densities of owls appear to be on the Yakima Indian Reservation (recovery contributions provided by the Yakima Nation are described in section II.C.8.).

Table 3.9. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the eastern Washington Cascades province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J.4.)

	Acreage			Owl Pairs			
DCA Ident. Number	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
WD-1N	34,525	99	25,640	6	0	8	8
WD-5	88,136	61	33,240	9	2	11	14
WD-6	92,263	93	54,520	12	1	16	24
WD-7	112,052	91	58,960	7	1	15	28
WD-12	64,439	97	29,280	8	0	8	16
WD-14	11,305	100	3,520	2	0	2	2
WD-15	52,167	97	33,400	2	0	9	13
WD-16	60,639	74	31,640	8	6	9	11
WD-20	26,668	93	9,120	3	0	3	5
WD-21	24,572	71	4,680	6	0	6	5
WD-22	11,107	68	1,680	2	0	2	2
WD-23	13,222	85	6,440	1	0	2	3
WD-24	68,544	100	37,760	5	0	10	18
WD-33	55,176	96	5,600	2	0	6	10
WD-37	16,935	97	1,400	1	0	2	2
WD-38	23,878	100	3,040	3	0	3	4
WD-39	11,480	100	1,920	1	0	1	1
WD-40	20,104	100	4,880	1	0	2	2
WD-41	12,803	100	3,480	1	0	1	2
WD-42	26,245	100	11,200	3	0	3	5
WD-44	9,962	100	3,000	1	0	1	1
Totals:	**836,222**	**90**	**364,400**	**84**	**10**	**120**	**176**
Totals for all lands in province:			**798,394**	**121**	**36**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.10. Summary comments on the designated conservation area (DCA) network in the eastern Washington Cascade province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
WD-6, WD-7	These are the category 1 DCAs in the province. They are currently estimated to contain fewer than 20 pairs of owls, but each has the potential to increase to 20 pairs.
WD-1N, WD-5, WD-12, WD-14 through WD-16, WD-20 through WD-24, WD-33, WD-37 through WD-42, and WD-44	Because of natural habitat limitations and low population densities, these remaining DCAs are all category 2s. They have potential capabilities to support from 1 to 18 pairs of owls. They were delineated in this area to address local demographic, distribution, and linkage concerns.

General threats to spotted owls in the province include loss of habitat, habitat fragmentation, lack of stable owl populations, and high risk of large-scale fire and insect damage (Appendix F). Historically, ground fuels were decreased by frequent fires that occurred as low intensity underburns that burned without killing overstory trees. A history of fire suppression has resulted in an accumulation of fuels, especially on national forest lands. This accumulation increases the probability of stand-replacement fires that potentially could eliminate northern spotted owl habitat from large-scale landscapes.

Three areas of special management emphasis have been identified for recommendations on nonfederal lands; specific recommendations are provided to help alleviate threats to owls in these areas.

Biological goals and implementation on federal lands

It is recommended that two category 1 DCAs, and 19 category 2 DCAs be established in this province (Tables 3.6 and 3.7). They vary in size from 9,900 acres to more than 112,000 acres, and include a total of 94 owl pairs of which 84 are located on federal lands. These represent 69 percent of the total known owl pairs on federal lands (Table 3.9 and Figure 3.13). The DCAs contain 46 percent of the nesting, roosting, and foraging habitat on federal land (Figure 3.14).

The DCA recommendations for the area north of Lake Chelan (north of DCAs WD-37 and WD-38) reflect low viability of owl populations that result from natural and human-caused habitat fragmentation. In this area, all known activity centers have been delineated as small DCAs. Any future activity centers that are located also should be added to the DCA network. The long-term recovery objective in this area is to develop small DCAs with owl clusters of two or more pairs, since category 1 DCAs are not possible.

In addition to the DCA network, threats to the owls in the province require areas of specific matrix management recommendations. The bulk of federal matrix land is recommended for management prescription A (see III.C.2.), but

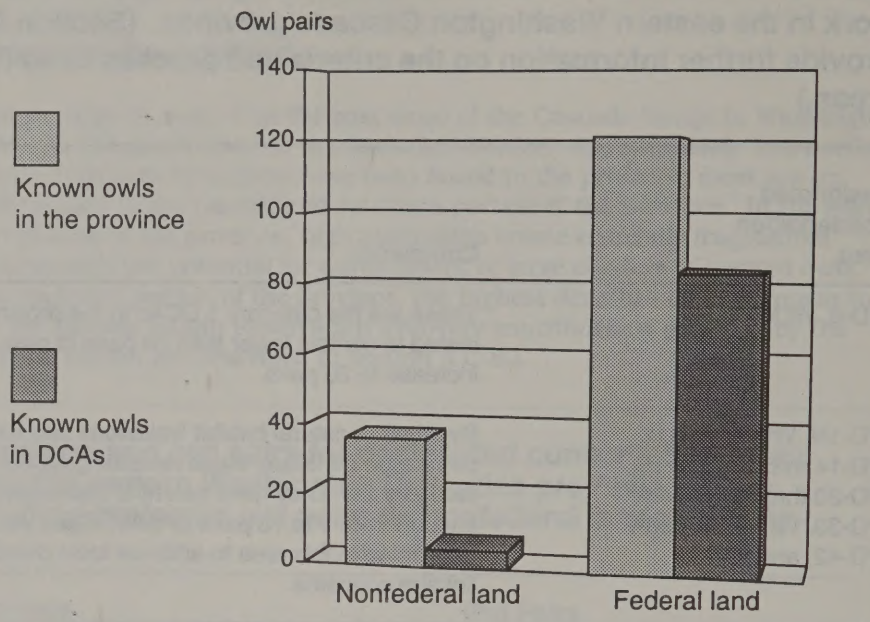


Figure 3.13. Known owl pairs in the eastern Washington Cascades province and in DCAs within the province.

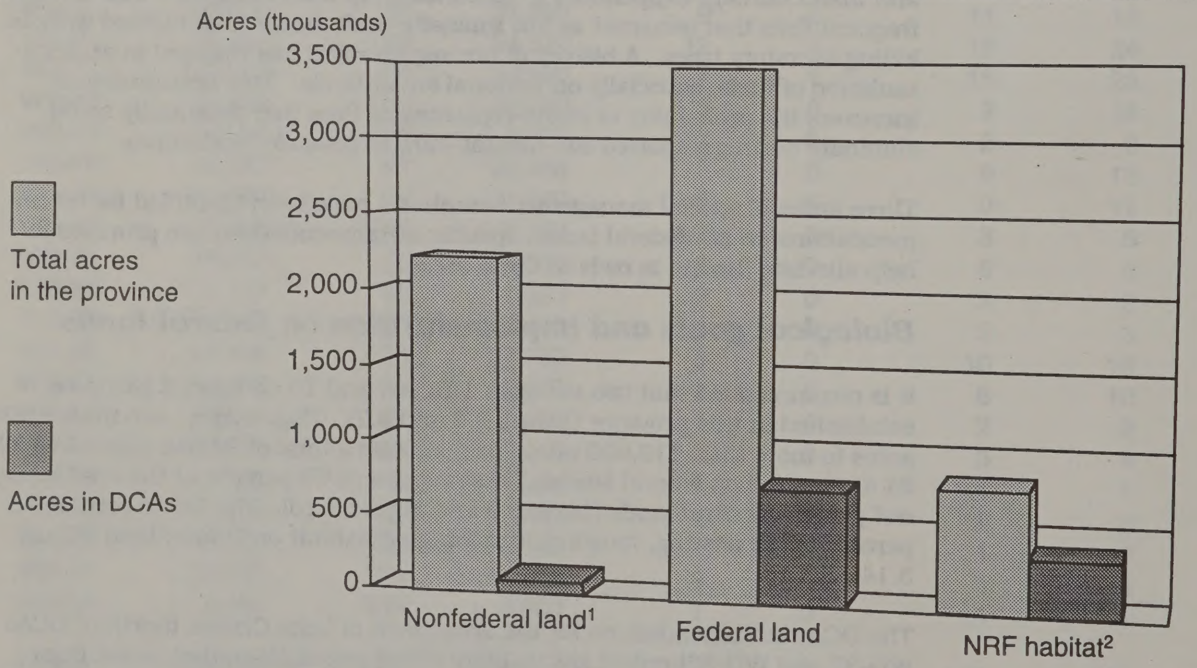


Figure 3.14. Acres in the eastern Washington Cascades province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

seven areas have been identified as needing prescription B or C. In most cases these federal matrix prescription areas correspond with areas of special management emphasis discussed for nonfederal lands.

In the Interstate 90 corridor, reserved pair areas are required to compensate for deficiencies in the DCA network (section III.C.2.). Population deficiencies in DCAs require reserved pair areas totaling 16,643 acres and five known owl activity centers. Habitat for these reserved pair areas also will alleviate the threat of impaired owl dispersal through this checkerboard ownership, and should be coordinated with nonfederal landowners.

Managed pair areas (prescription C matrix management) are located on federal land within high fire-risk mixed conifer and ponderosa pine forests of the province. Five areas are delineated where managed pair areas are recommended for all currently known spotted owls on federal land, and those discovered in the future. These areas are:
- Between WD-1 and WD-1N: three known activity centers to be protected,
- Among WD-16, WD-15, WD-12 and WD-14: seven known activity centers,
- Between WD-5 and WD-6: two known activity centers,
- Among WD-6, WD-21 and the eastern province boundary: three known activity centers,
- Among WD-7, WD-21 and WD-22: four known activity centers.

Based on these known owl activity centers, a total of 19 known activity centers and 108,176 acres would be included in prescription C managed pair areas.

Biological goals and implementation on nonfederal lands

Three areas are identified for special management emphasis on nonfederal lands. In all three cases, recommendations are made for nonfederal lands to augment federal management in addressing threats to owl populations.

In the Interstate 90 corridor area of checkerboard ownership. Habitat loss and north-to-south connectivity among DCAs are the main concerns. It is recommended that nonfederal lands provide nesting, roosting, and foraging habitat for spotted owls within or directly adjacent to federal DCAs WD-5, WD-6, WD-7, and WD-16. It is recommended that dispersal habitat be provided among these DCAs. The goal is to contribute to owl population stability within the DCAs. Managed suitable habitat is expected to provide characteristics necessary for roosting and foraging, but not necessarily for nesting. Some nesting habitat may be needed in the short term, especially since the DCAs are deficient in owl pairs.

Endangered Species Act prohibition of take currently is contributing to the objective of augmenting checkerboard DCAs in the Interstate 90 corridor. Nonfederal landowners currently are affected by prohibitions on take involving many owl sites in the general area identified for special management emphasis. Protective management as described in section III.C.3. could lead to more efficient conservation measures and improve achievement of recovery objectives. New forestry techniques already are practiced by some landowners in this area, and should contribute to achieving objectives within DCAs. State forest practices rules could be used to ensure protection of known owls. In some areas where there is adequate federal nexus, federal critical habitat designation could provide protection beyond that available through other means. Land exchange also may be a useful and accepted mechanism in these checkerboard ownership areas. Land purchase may be needed for small acreage landowners.

An additional recommendation to alleviate threats in the Interstate 90 corridor is to develop habitat on the L.T. Murray Wildlife Area to support a large cluster of owl pairs (more than 20 pairs) in conjunction with

habitat in DCA WD-16. Approximately 20,000 acres are needed to achieve this objective. The L.T. Murray Wildlife Area is owned by the State of Washington and most of the land is dedicated to wildlife habitat uses. Although there is little spotted owl nesting, roosting, or foraging habitat in the area now, development of habitat over time is possible. The recovery plan recommends that mixed conifer habitat in this area be managed to develop old-growth and other late successional forest characteristics. This will contribute to the recovery objective.

Checkerboard ownership north from WD-6 and extending to area surrounding and adjacent to WD-20, WD-21, and WD-22. In this area, the concerns and recommendations are the same as described for the Interstate 90 corridor.

Two other areas of special management emphasis are nonfederal lands between the Yakima Indian Reservation and federal DCAs (between WD-12 and the reservation, and between the reservation and WD-1). The recommendation for these areas is to provide dispersal habitat. Dispersal areas should be as continuous as feasible, and broad enough to allow a reasonable likelihood that owls will stay within them as they move between DCAs. In the southern area, this dispersal habitat will improve dispersal opportunities adjacent to the Columbia River Gorge.

Much of this area is currently in uneven-age management, which in many cases provides dispersal habitat and perhaps foraging habitat. Development of new forestry practices and uneven-aged management may improve the contribution to recovery. Protective management, as described in section III.C.3., could contribute to this objective. If new state forest practices regulations were developed, such regulations could contribute to this objective.

Oregon Coast Range Province

Province description

This province covers approximately 4.5 million acres in western Oregon between Washington and the Oregon Klamath province. Ownership is 57 percent private, 30 percent federal, and 13 percent state lands. The Grand Ronde and Siletz Indian Reservations lie within the province; contributions from these Indian lands are discussed in section II.C.8. Federal lands include the Siuslaw National Forest and portions of four BLM districts. BLM lands are distributed in a checkerboard ownership pattern through much of the province. Approximately 325 northern spotted owl pairs are known to occur in the province. Thirty-two percent of the pairs are in the southern portion of the province, south of Highway 38 primarily on BLM lands.

Severe threats to the spotted owl exist in this province including low and declining populations, little nesting, roosting, and foraging habitat (only 15 percent of the province), poor distribution of remaining owls and owl habitat, and high levels of predators. There is poor habitat and population connectivity both within the province and with adjoining provinces.

Four areas of special emphasis have been identified. Reduced habitat and poor population connectivity are problems in all four areas.

Tillamook/Astoria area. Forest stands in this area are primarily young and homogeneous due to past fires and logging. Federally owned lands comprise a small proportion of the ownership and are unlikely to make major contributions to recovery. Suitable habitat and owl populations are at extremely low levels.

Middle Oregon Coast (Highway 18 to Highway 34). Ownership in this area is primarily nonfederal. Currently, nesting, roosting, and foraging habitat is limited in the recommended DCAs, due to timber harvest. Habitat to support dispersal among the DCAs also is limited.

Eugene and Drain Corridor. Nesting, roosting, and foraging habitat has been reduced and fragmented in recommended DCAs, due to timber harvest. Habitat among the DCAs between the Oregon coast and the western Oregon Cascades is highly fragmented, thus reducing its suitability for dispersal.

Area south of Highway 38. Nesting, roosting, and foraging habitat is limited within recommended DCAs. Habitat for dispersal is limited among DCAs and between this province and the Oregon Klamath province, due to harvest patterns within areas of checkerboard ownership.

Biological goals and implementation on federal land

Seventeen DCAs are recommended for this province, with five DCAs meeting category 1 criteria (Tables 3.11 and 3.12). A total of 110 pairs of owls has been

Table 3.11. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the Oregon Coast Range province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J. 5.)

	Acreage			Owl Pairs			
DCA Ident. Number	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
OD-27	77,749	67	27,320	15	1	12	20
OD-28	70,663	69	26,720	19	5	15	20
OD-29	50,636	82	28,360	9	1	10	15
OD-30	59,934	57	15,760	14	4	10	12
OD-31	70,555	84	31,760	14	0	14	20
OD-32	39,894	75	15,000	5	0	5	10
OD-33	60,175	61	9,640	5	0	5	12
OD-34	50,661	49	24,600	7	0	7	15
OD-35	51,780	86	17,800	3	0	3	15
OD-36	70,212	76	9,720	3	0	3	18
OD-37	46,239	58	2,920	2	2	3	7
OD-38	8,942	54	1,240	1	0	1	1
OD-49	22,352	13	800	1	0	1	1
OD-50	51,050	17	240	2	2	2	4
OD-53	86,004	91	38,440	8	0	12	30
OD-54	8,509	58	2,640	2	0	1	2
OD-55	2,713	53	200	0	0	0	1
Totals:	**828,068**	**69**	**253,160**	**110**	**15**	**104**	**203**
Totals for all lands in province:			**437,494**	**269**	**57**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details. This may be smaller than the current known number where populations are adjusting to rapidly changing habitat conditions.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.12. Summary comments on the designated conservation area (DCA) network in the Oregon Coast Range province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
OD-27, OD-31, OD-53	These category 1 DCAs currently contain fewer than 20 owl pairs, but have a future capability of supporting more than 20 owl pairs, based on federal habitat.
OD-28	This category 1 DCA currently supports more than 20 owl pairs, but requires nonfederal contribution to do so. Future federal habitat capability is for 20 owl pairs.
OD-36	This category 1 DCA currently contains fewer than 20 owl pairs. However, it has a future capability of supporting more than 20 owl pairs with a relatively small nonfederal contribution.
OD-30 and OD-33	These are category 2 DCAs with less than 20 owl pairs, based on federal habitat only. If significant nonfederal contributions are obtained, the areas are capable of supporting more than 20 owl pairs.

located on federal lands within these DCAs between 1986 and 1990. This represents approximately 40 percent of the 268 pairs located on all federal land during that same period (Figure 3.15). The DCAs contain about 58 percent of the nesting, roosting, and foraging habitat identified on federal land (Figure 3.16).

Federal matrix management in the Oregon Range Coast province will require prescription A and prescription B management areas. Because of the low number of pairs within DCAs north of Highway 38, an estimated 57 reserved pair areas (prescription B) should be established to supplement the DCAs. Three additional reserved pair areas should be established southeast of OD-27 to supplement the population in that DCA. The remainder of the federal matrix in this province should be managed for dispersal habitat under matrix prescription A (section III.C.2.). Residual habitat areas of 100 acres each should be established for all known and future-discovered activity centers up to a density of eight areas per township.

With the addition of the reserved pair areas, approximately 60 percent of all known pairs on federal lands within the province will be protected by this plan. Nearly all known pairs on federal lands north of Highway 38 will be protected.

Biological goals and implementation on nonfederal land

General goals for nonfederal lands are to (1) provide nesting, roosting, and foraging habitat within federal DCAs with checkerboard ownership; (2) provide dispersal habitat in all special management emphasis areas; (3) encourage cooperative management on state lands to provide nonfederal clusters of owls and dispersal habitat among clusters; and (4) develop a cooperative habitat management plan for the Elliott State Forest. Specific objectives and implementation approaches are described later.

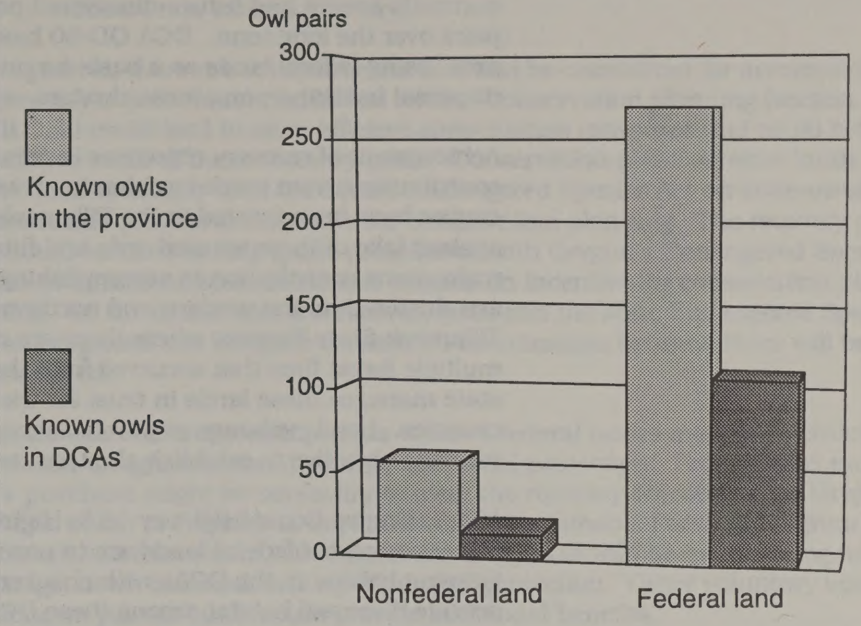


Figure 3.15. Known owl pairs in the Oregon Coast Range province and in DCAs within the province.

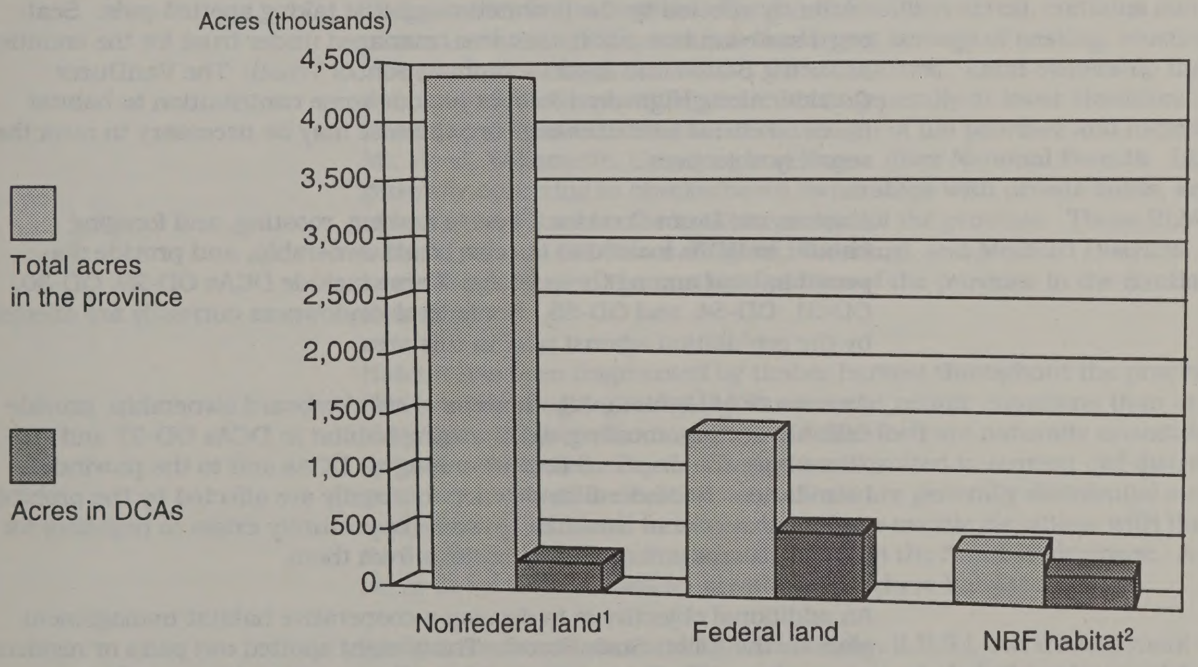


Figure 3.16. Acres in the Oregon Coast Range province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

Tillamook/Astoria area. Provide supplemental pair areas to protect currently known and future-discovered pairs and manage for clusters of pairs over the long term. DCA OD-50 has been recommended in this area, using federal lands as a basis for one of these clusters. Provide dispersal habitat among these clusters.

Achievement of recovery objectives in this area will depend largely on contributions from nonfederal lands. Fourteen spotted owl pairs or singles have been located in the Tillamook/Astoria area. Prohibition against take of these spotted owls and future-discovered spotted owls will make some contribution to accomplishing objectives. Most of these sites are clustered on the western and northern sides of the Clatsop and Tillamook State Forests, where there are mature stands that survived the multiple forest fires that occurred from the 1930s until early 1950. The state manages these lands in trust for the fiduciary benefit of the local counties. Land exchange or purchase may be necessary to meet the recovery objective to establish clusters and assure long term recovery.

Middle Oregon Coast (Highway 18 to Highway 34). The province recovery objectives on nonfederal lands are to provide nesting, roosting, and foraging habitat in the DCAs with checkerboard ownership, and to provide dispersal habitat among these DCAs. The DCAs needing supplemental habitat include OD-33, OD-37, OD-38, and OD-49. The recommendation for dispersal habitat applies to nonfederal land throughout this area. The objective of providing habitat within these DCAs is to meet, in conjunction with habitat on federal land, the owl population objectives for the DCAs. Some opportunity may exist to negotiate for the best combinations of contributions from nonfederal landowners since they are currently affected by the prohibition against taking spotted owls. Scattered state lands occur in this area, managed under trust for the counties or for the State Land Board (Common School Trust). The VanDuzer Corridor along Highway 18 could provide some contribution to habitat needs. Federal land exchange or purchase may be necessary to meet the recovery objectives.

Eugene and Drain Corridor. Provide nesting, roosting, and foraging habitat in DCAs located in checkerboard ownership, and provide dispersal habitat among these DCAs. These include DCAs OD-29, OD-30, OD-31, OD-54, and OD-55. Nonfederal landowners currently are affected by the prohibition against take in this area.

Area south of Highway 38. In areas of checkerboard ownership, provide suitable nesting, roosting, and foraging habitat in DCAs OD-27 and OD-28 and provide dispersal habitat among all DCAs and to the province boundaries. Nonfederal landowners currently are affected by the prohibition against take in this area, so some opportunity exists to negotiate for the best combination of contributions from them.

An additional objective is to develop a cooperative habitat management plan for the Elliott State Forest. Thirty-eight spotted owl pairs or resident singles have been located in this forest. As a result, the state forest is currently contributing to recovery due to prohibitions against take. Conservation planning as described in section III.C.3. for the Elliott State Forest could lead to more efficient conservation measures and improve the likelihood of achieving recovery objectives. State lands also are affected by Oregon's Endangered Species Act. A conservation plan could be used to comply with the state's Endangered Species Act on state-owned lands. In addition, the Mill Creek and Umpqua River drainages have been designated by the State Land Board as areas that will be

managed for nontimber values. This management will provide some contribution toward recovery.

In general, there are several means that can be considered for accomplishing recovery objectives on nonfederal lands. Conservation planning (section III.C.3.) could lead to more efficient conservation measures and could help achieve some of these recovery goals. Conservation plans on state lands could be used to comply with the state's Endangered Species Act on state-owned lands and provide an incentive for conservation planning. The recovery plan should be used to help guide compliance with Oregon's Endangered Species Act programs on state lands and provide an incentive for conservation planning. To the extent that the recovery plan and the state Endangered Species Act programs can be made consistent, coordination between them will be improved.

In checkerboard ownership areas where a federal nexus may exist, critical habitat designation could provide additional protection. Federal land exchange or purchase might be necessary to meet the recovery objective. The Oregon Department of Forestry is implementing a Sustainable Forestry Program on state lands that would yield additional benefits to wildlife by providing more snags, down material, and riparian zone protection. Other voluntary contributions on private lands could provide additional benefits.

Western Oregon Cascade Province

Province description

This province is the largest in Oregon (6.9 million acres), contains more documented owl pairs (925), and has the largest acreage of nesting, roosting, and foraging habitat (approximately 1,918,000 acres). Land ownership throughout the province is mixed, with private lands generally at lower elevations. National forest land extends almost the length of the province and includes the Mt. Hood, Willamette, Umpqua, and Rogue River National Forests. BLM lands, generally occurring in checkerboard ownerships with private lands, are located at lower elevations on the western portion of the province. These BLM lands include parts of the Salem, Eugene, Roseburg, and Medford Districts. State lands are present in the northern portion of the province in the Santiam State Forest.

Habitat has been fragmented by timber harvest throughout the province. However, the fragmentation is less severe at middle elevations than at lower elevations. Higher elevations (above 4,500 feet) are naturally unsuitable as spotted owl habitat. This landscape has resulted in current owl distribution generally in the mid-elevation zone. Owls are generally distributed continuously through national forest lands at these middle elevations with the exception of the checkerboard ownership lands in the Santiam drainage. A few owls occur at lower elevations on private lands where habitat remains.

As discussed in Status and Threats (section II.B.5.), owl management concerns in the province are varied. These concerns include habitat loss and fragmentation (71 percent of the province is considered unsuitable habitat due to timber harvest); declining populations; and poor population connectivity with adjacent provinces due to checkerboard ownership, timber harvest, and the Columbia River Gorge.

Two areas of special management emphasis have been identified. In each area, there are two main concerns. The first is the pattern of checkerboard ownership within DCAs. Federal lands alone in these DCAs would be inadequate to fully meet the DCA objectives. The second main concern is poor population

connectivity between key DCAs. This results in weak linkages between the western Oregon Cascades province and the Oregon Coast Range and California Cascades provinces. Specific concerns for these areas of special management emphasis follow.

Area between the Oregon Coast Range and Oregon Klamath provinces and the western Oregon Cascades province (this includes OD-11, OD-12, OD-17, OD-39, OD-56, OD-57, OD-58). Dispersal habitat in this area has been reduced and fragmented due to timber harvesting, which reduces the likelihood of successful owl dispersal. In addition, most of these DCAs consist of checkerboard ownership, and federal land in these DCAs is generally not adequate to fully accomplish the DCA objectives.

Area south of OD-19. Several concerns exist; habitat among DCAs OD-19, OD-40, and the California provinces has been reduced and fragmented by timber harvest; there is a compounding risk of habitat loss from fire (Appendix F). Also, checkerboard ownership in DCAs reduces capability to achieve DCA objectives solely on federal lands.

Biological goals and implementation on federal lands

Using the design criteria for the DCA network and future habitat capability estimates, 17 category 1 DCAs and five category 2 DCAs are recommended for this province (Tables 3.13 and 3.14). These areas currently contain 413 documented owl activity centers (357 pairs and 56 territorial singles). The pairs included on federal lands in DCAs represent approximately 41 percent of pairs (Figure 3.17) located on federal lands in this province in the last 5 years. The DCAs contain about 42 percent of the nesting, roosting, and foraging habitat identified on federal lands in the province (Figure 3.18). The majority of these DCAs are in national forests; eight occur on BLM lands.

Generally, federal matrix management will follow prescription A, with the federal landscape meeting the 50-11-40 rule and residual habitat areas established around activity centers outside of DCAs, up to a density of eight areas per township. The exception to this general matrix management is the need for one reserved pair area, west of OD-19 to supplement the known pairs in this DCA.

Biological goals and implementation on nonfederal lands

As with other provinces, the recommendations for nonfederal lands focus on the areas of special management emphasis. These areas and concerns about them are:

Area between the /regon Coast Range and Oregon Klamath provinces and the western Oregon Cascades province (this includes OD-11, OD-12, OD-17, OD-39, OD-56, OD-57, OD-58). Within DCAs in checkerboard ownership in the areas of special management emphasis, provide habitat suitable for nesting, roosting, foraging, and dispersal. This will include DCAs OD-12, OD-17, OD-39, OD-40, OD-56, OD-57, and OD-58. The objective of providing habitat within the DCAs is to fully meet, in conjunction with habitat on federal land, the objectives for the DCAs.

In addition to providing nesting, roosting, and foraging habitat as needed, nonfederal lands should provide dispersal habitat among the DCAs in these areas of special management emphasis. In the portion of the western Oregon Cascades that connects to the southern Oregon Coast, dispersal habitat should generally be provided within an area that encompasses OD-11, OD-12, OD-58, OD-57, OD-56, and OD-39.

Area south of OD-19. In the southern portion of the western Oregon Cascades, dispersal habitat should be provided in a band that generally connects OD-19, OD-20, and OD-40.

Currently, the federal Endangered Species Act requirements prohibiting take are contributing to partial fulfillment of the nonfederal recommendations in the province, but some of the guidelines do not contribute effectively to the goal of providing dispersal habitat. Protective management (section III.C.3.) could lead to more efficient conservation measures.

Federal land exchange or purchase may be necessary to meet the recovery objectives for nonfederal land in this province. Land exchange would be

Table 3.13. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the western Oregon Cascades province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J.6.)

DCA Ident. Number	Acreage: Total	Acreage: Percent Federal Land[1]	Acreage: NRF Habitat Federal[2]	Owl Pairs: Known Owls[3] Federal	Owl Pairs: Known Owls[3] Nonfed	Owl Pairs: Current Projected Federal[4]	Owl Pairs: Future Projected Federal[5]
OD-1	148,299	99	95,280	9	0	30	42
OD-3	111,716	100	60,560	19	0	23	35
OD-4	98,610	91	50,840	13	0	20	30
OD-5	80,982	95	38,560	23	0	22	30
OD-6	81,251	93	49,520	18	0	25	30
OD-7	67,248	94	40,280	23	0	23	30
OD-8	103,792	100	78,480	21	0	25	28
OD-9	84,370	100	40,480	25	0	25	33
OD-10	80,087	100	43,600	16	0	20	30
OD-11	65,444	93	34,000	22	0	20	25
OD-12	89,741	57	32,280	29	0	20	23
OD-13	92,956	97	56,160	27	0	25	35
OD-14	82,090	96	52,240	29	1	25	33
OD-15	88,789	91	45,240	16	0	18	25
OD-17	55,174	58	20,320	24	4	13	20
OD-18	66,504	96	28,175	20	0	18	25
OD-19	86,433	93	39,365	14	0	14	23
OD-39	12,504	55	920	2	0	1	1
OD-40	43,122	69	8,440	6	0	5	10
OD-56	2,960	59	360	0	0	0	1
OD-57	2,610	61	440	0	0	0	1
OD-58	2,648	55	560	1	0	1	1
Totals:	**1,547,330**	**92**	**816,100**	**357**	**5**	**373**	**511**
Totals for all lands in province:			**1,942,336**	**876**	**49**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.14. Summary comments on the designated conservation area (DCA) network in the western Oregon Cascades province. (Section III.C.2.a. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
OD-5, OD-7, OD-8 OD-9, OD-11, OÎ-12, OD-13 and OD-14	These category 1 DCAs each currently support 20 or more pairs of owls.
OD17 and OD-18	These category 1 DCAs each currently support 20 or more pairs of owls but require both federal and nonfederal land to do so. In the future, they will be able to support 20 pairs solely on nonfederal lands.
OD-1, OD-3, OD-4 OD-6, OD-10, OD-15 and OD-19	These category 1 DCAs are currently estimated to contain fewer than 20 pairs of owls. Each DCA has the potential to increase up to 20 pairs.
OD-40	This DCA is recommended to provide population connectivity to the California Cascades province. It is estimated to support 14 pairs of owls in the future.
OD-39, OD-56, OD-57,	These DCAs provide an important linkage between the western Oregon Cascades province and the Oregon Coast Range province.

extremely expensive and depend on legal restrictions. In checkerboard ownership areas where a federal nexus exists, designating the land as critical habitat might provide additional protection.

Some state lands do not lie within the areas of special management emphasis, but are contributing to more general recovery goals in the province. The southern portion of Oregon's Santiam State Forest lies between DCAs OD-4 and OD-6. This state land is managed in trust for the fiduciary benefit of the local counties and currently is managed to provide for owl dispersal between these DCAs. Voluntary contributions by the state's Sustainable Forestry Program and private landowners could provide additional benefits. Silver Falls State Park is another parcel of state land which contributes to recovery by providing nesting, roosting, and foraging habitat.

The recovery plan should be used to help guide compliance with Oregon's Endangered Species Act programs on state lands and provide an incentive for conservation planning. To the extent that the recovery plan and the state Endangered Species Act programs can be made consistent, coordination between them will be improved.

Eastern Oregon Cascades Province

Province description

The eastern Oregon Cascades province extends from the Columbia River to the California border but occupies only a narrow area between Highway 97 and the

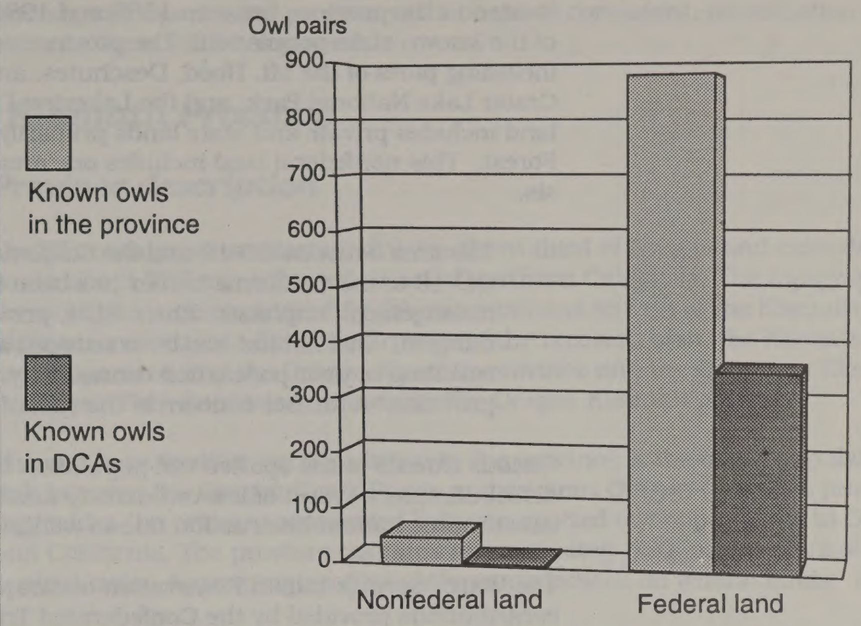


Figure 3.17. Known owl pairs in the western Oregon Cascades province and in DCAs within the province.

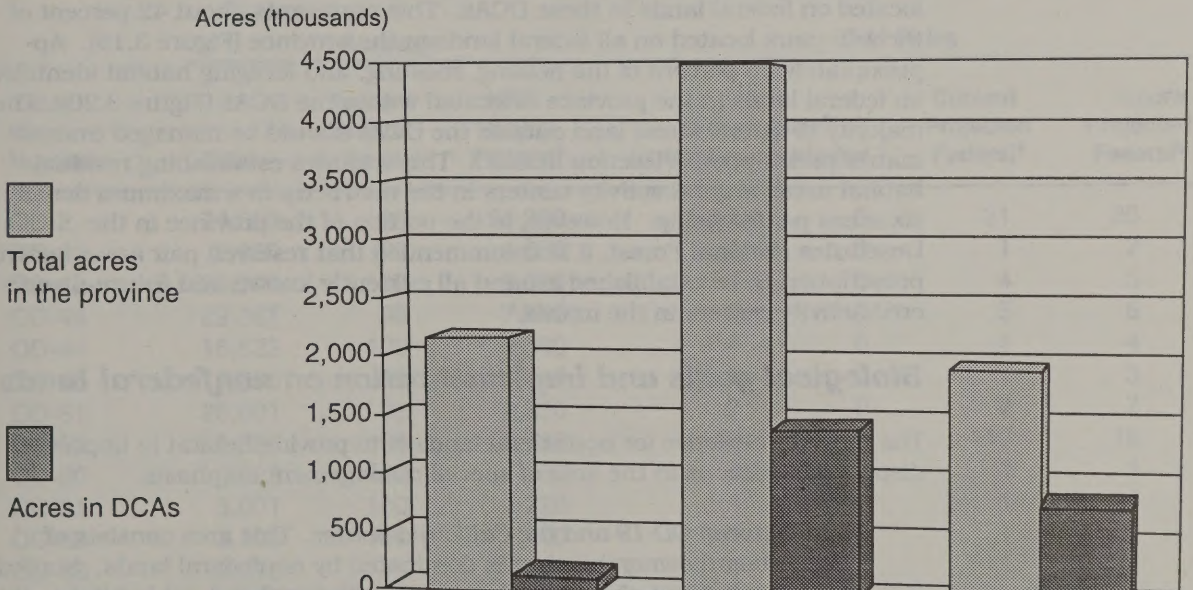


Figure 3.18. Acres in the western Oregon Cascades province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

crest of the Cascade Mountains. There were approximately 163 owl pairs located in the province between 1986 and 1990, representing about 9 percent of the known state population. The province consists primarily of federal land, including parts of the Mt. Hood, Deschutes, and Winema National Forests, Crater Lake National Park, and the Lakeview District of the BLM. Nonfederal land includes private and state lands primarily south of the Winema National Forest. This nonfederal land includes one area of special management emphasis.

The area between OD-19 and the California border. The area from DCA OD-19 to the California border has been identified as an area for special management emphasis, where BLM, private, and state lands are intermingled. Owl habitat has been reduced and fragmented in this area, resulting in poor population connectivity with the California Cascades province. A further concern is the risk of habitat loss from fire.

Serious threats to the spotted owl population in the province include poor distribution as a result of low owl density and fragmented habitat, and risk of catastrophic habitat destruction due to wildfire (section II.B. and Appendix F).

The Warm Springs Indian Reservation occurs within this province. Recovery contributions provided by the Confederated Tribes of the Warm Springs are described in section II.C.8.

Biological goals and implementation on federal lands

One category 1 DCA and 12 category 2 DCAs are recommended in this province (Tables 3.15. and 3.16.). Approximately 62 pairs of owls have been located on federal lands in these DCAs. This represents about 42 percent of the 146 pairs located on all federal lands in the province (Figure 3.19). Approximately 26 percent of the nesting, roosting, and foraging habitat identified on federal lands in the province is located within the DCAs (Figure 3.20). The majority of federal forest land outside the DCAs should be managed under matrix prescription A (section III.C.2.). This includes establishing residual habitat areas around activity centers in the matrix up to a maximum density of six areas per township. However, in the portion of the province in the Deschutes National Forest, it is recommended that reserved pair areas (matrix prescription B) be established around all currently known and future-discovered activity centers in the matrix.

Biological goals and implementation on nonfederal lands

The recovery objective for nonfederal lands is to provide habitat to improve dispersal conditions in the area of special management emphasis.

Area between OD-19 and the California border. This area consists of checkerboard ownership, but is dominated by nonfederal lands. Nonfederal contributions should work in conjunction with federal habitat in this area to provide for dispersal between the eastern Oregon Cascades and the California Cascades. Where ecological potential exists, nesting habitat also could be provided in this area to improve the likelihood of dispersal among provinces. The prohibition on take is unlikely to make substantial contributions toward meeting these objectives because few owl sites are known on nonfederal lands in this area.

The recovery plan should be used to help guide compliance with Oregon's Endangered Species Act programs on state lands and provide an incentive for

conservation planning. To the extent that the recovery plan and the state Endangered Species Act programs can be made consistent, coordination between them will be improved.

Oregon Klamath Province

Province description

The Klamath province starts in the southern third of Oregon and extends south about 250 miles through most of northern California. The topography of the province is characterized by the mountainous terrain of the Klamath and Siskiyou mountains. For the purposes of the recovery plan, the Klamath has been separated into the Oregon Klamath province and the California Klamath province. This discussion focuses on the Oregon Klamath province.

The northern spotted owl population in the province is the major population link between the Oregon Coast Range and western Oregon Cascades provinces. It provides the primary connection between spotted owl populations in Oregon and California. The province contains approximately 390 known pairs of spotted owls. Approximately 360 of these are located on federal lands. Na-

Table 3.15. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the eastern Oregon Cascade province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J.7.)

	Acreage			Owl Pairs			
DCA Ident. Number	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
OD-2	74,558	99	51,200	21	0	21	26
OD-41	9,855	90	4,560	1	0	1	2
OD-42	20,000	100	8,520	4	0	4	5
OD-43	29,367	98	7,840	5	0	5	6
OD-44	16,532	100	8,560	4	0	4	4
OD-45	18,256	99	4,240	1	0	1	3
OD-51	28,601	99	9,320	7	0	7	7
OD-59	41,858	95	20,783	13	0	13	18
OD-60	3,023	100	480	1	0	1	1
OD-61	3,001	100	720	1	0	1	1
OD-62	2,705	100	1,400	1	0	1	1
OD-63	3,013	71	800	1	0	1	1
OD-64	3,063	100	520	1	0	1	1
OD-65	3,028	82	760	1	0	1	1
Totals:	**256,860**	**98**	**119,703**	**62**	**0**	**62**	**77**
Totals for all lands in province:			**455,156**	**146**	**17**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.16. Summary comments on the designated conservation area (DCA) network in the eastern Oregon Cascades province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
OD-2	This category 1 DCA, entirely on federal lands, supports more than 21 owl pairs. It has a future capability of supporting 26 owl pairs.
OD-41 through OD-45, OD51, and ODA-59 through OD-65	The scattered distribution of owls and owl habitat on the east side of the Cascades prevented delineating large DCAs capable of supporting 20 owl pairs either now, or in the future.

tional forests and BLM lands compose the majority of the province. Unlike the California Klamath province, few spotted owl activity centers are known on private lands, though 34 percent of the province is in private ownership. These private lands are located at lower elevations intermixed with BLM lands in a checkerboard ownership pattern. A small amount of state forest land is located in the province, including some state land within the perimeters of recommended DCAs. Despite the mixed ownership in the province, most suitable habitat currently exists on federal lands.

Serious threats to the owl population in the Oregon Klamath province include loss and fragmentation of habitat due to timber harvest and fires (Appendix F); a declining population as demonstrated in density study areas (Appendix C); and weak population connectivity within the province and with adjacent provinces because of poor habitat conditions in areas of checkerboard ownerships.

The area of checkerboard ownership in the north and east half of this province has been identified as a special emphasis area for recommendations on non-federal lands.

Area of checkerboard ownership in the north and east half of the province: This area is of concern because: 1) nesting, roosting, and foraging habitat has been fragmented by timber harvest in checkerboard ownership areas; 2) dispersal habitat has been reduced and fragmented by timber harvest; and 3) the risk of habitat loss to fire is high.

Biological goals and implementation on federal lands

Using the design criteria for the DCA network, nine DCAs are recommended within this province (Tables 3.17 and 3.18). Eight of the DCAs satisfy the criteria for category 1 DCAs. Only OD-52 does not. Two of the category 1 DCAs, OD-20 and OD-22, extend into California. Conversely, part of one California Klamath province DCA (CD-5) extends slightly into Oregon. (The data for these DCAs that cross state boundaries are presented in the province that includes the majority of the land.)

Currently there are 115 known pairs and 67 territorial singles on federal lands within the nine DCAs. The DCAs contain about 32 percent of the known pair

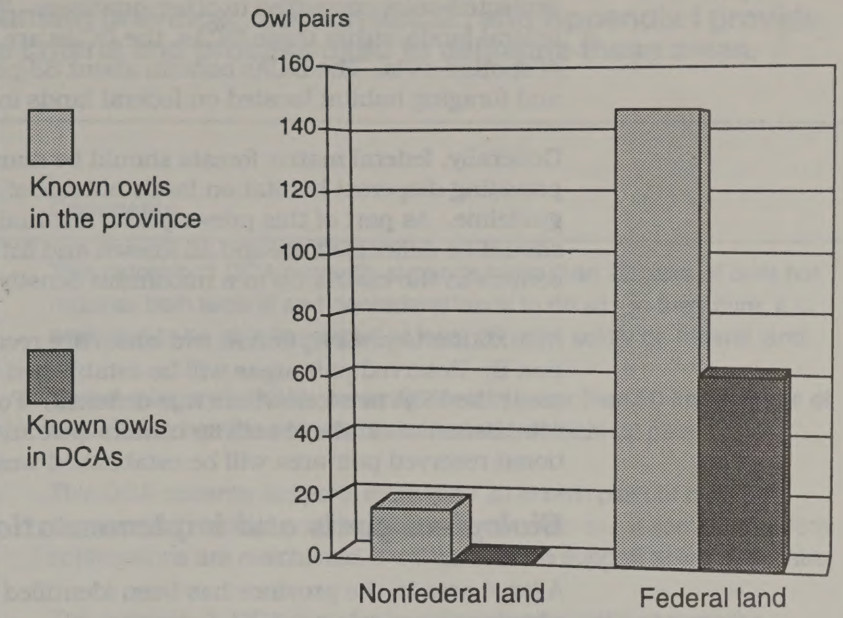


Figure 3.19. Known owl pairs in the eastern Oregon Cascades province and in DCAs within the province.

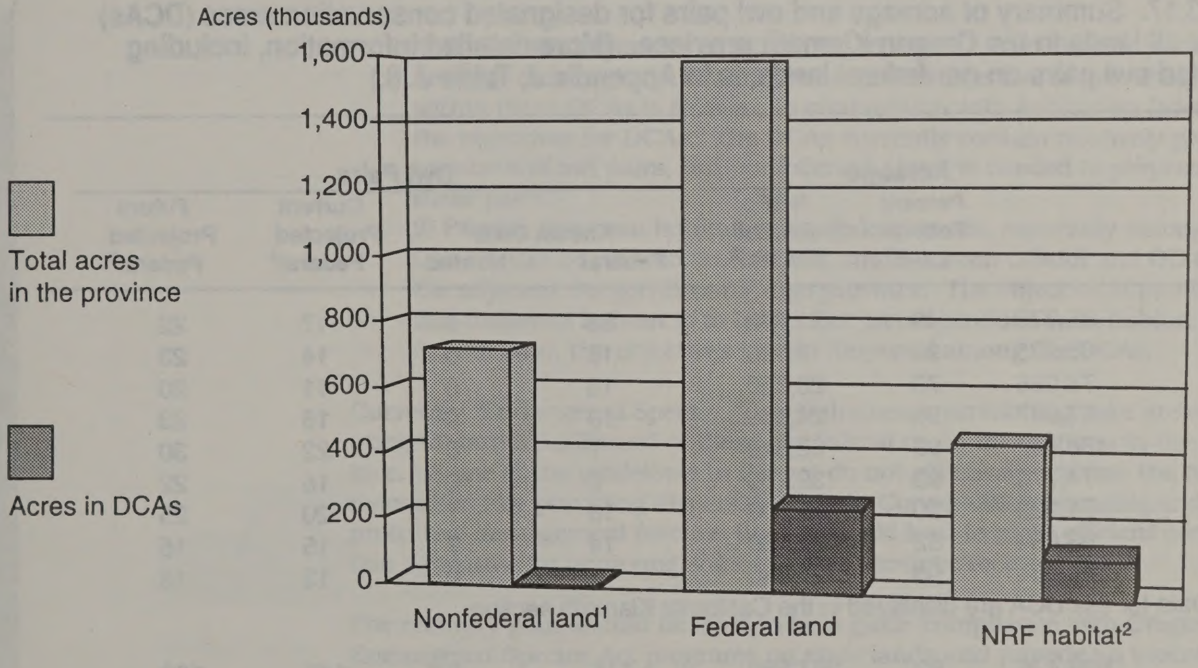


Figure 3.20. Acres in the eastern Oregon Cascades province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

sites on federal lands (figure 3.21). This is a relatively low percentage of known protected pairs compared to other provinces. When habitat has recovered on federal lands within these DCAs, the DCAs are expected to support 205 pairs of spotted owls. The DCAs contain about 53 percent of the nesting, roosting, and foraging habitat located on federal lands in the province (Figure 3.22).

Generally, federal matrix forests should be managed under prescription A, providing dispersal habitat on lands outside of DCAs following the 50-11-40 guideline. As part of this prescription, residual habitat areas of 100 acres should be delineated around all known and future-discovered owl activity centers in the matrix up to a maximum density of 10 areas per township.

In addition to prescription A, two zones are recommended for matrix prescription B. Reserved pair areas will be established in these locations to supplement the DCA network where it is deficient. Four reserved pair areas will be established around owl activity centers east and south of OD-21. One additional reserved pair area will be established west of OD-20.

Biological goals and implementation on nonfederal lands

A large area in the province has been identified for special management emphasis.

Table 3.17. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the Oregon Klamath province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J. 8.)

DCA Ident. Number	Acreage			Owl Pairs			
	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
OD-16	85,379	49	21,840	23	0	17	22
OD-20	65,225	94	19,400	15	0	14	23
OD-21	78,086	73	28,360	13	0	11	20
OD-22	67,047	96	24,560	19	0	18	23
OD-23	130,447	99	52,840	7	0	22	30
OD-24	74,770	93	39,760	6	0	15	22
OD-25	71,133	90	37,000	16	1	20	25
OD-26	86,684	52	22,160	14	7	15	15
OD-52	40,654	93	21,640	2	0	13	18
CD-5 Data for this DCA are displayed in the California Klamath section							
Totals:	**699,425**	**82**	**267,560**	**115**	**8**	**145**	**198**
Totals for all lands in province:				**501,872**	**358**	**29**	

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.18. Summary comments on the designated conservation area (DCA) network in the Oregon Klamath province. Section III.C.2.. and Appendix I provide further information on the criteria and process used to delineate these areas.

Designated Conservation Area	Comments
OD-16	This category 1 DCA currently supports more than 20 pairs of owls but requires both federal and nonfederal lands to do so. In the future, it is projected to be able to support at least 20 pairs solely on federal land.
OD-20 through OD-25	These category 1 DCAs currently contain fewer than 20 known pairs of owls. Each has the potential to increase to at least 20 pairs.
OD-26	This DCA currently supports more than 20 known pairs of owls but requires both federal and nonfederal lands to do so. If some nonfederal contributions are maintained, it will continue to support at least 20 pairs.
OD-52	This category 2 DCA includes low elevation habitat and provides distribution of the network into the northwest corner of the province.

All checkerboard lands in the north and east portions of the province. Two recommendations are made:

1) Within the perimeter of DCAs OD-16, OD-21, and OD-26, provide nesting, roosting, and foraging habitat. The objective of providing habitat within these DCAs is to meet, in conjunction with habitat on federal land, the objectives for DCAs. The DCAs currently contain relatively good numbers of owl pairs, but nonfederal habitat is needed to perpetuate these pairs.
2) Provide dispersal habitat on nonfederal lands, especially among DCAs OD-16, OD-24, OD-25, and OD-26, and between OD-26 and OD-27 in the adjacent Oregon Coast Range province. The objective of providing this dispersal habitat is to help meet, in conjunction with habitat on federal land, the objectives for owl dispersal among the DCAs.

Currently, Endangered Species Act requirements prohibiting take are contributing to partial fulfillment of these nonfederal recommendations in the province. Some of the guidelines in the act do not effectively address the recommendations by providing dispersal habitat. Conservation planning and protective management (section III.C.3.) could lead to more efficient conservation measures for achieving some of these province recovery goals.

The recovery plan should be used to help guide compliance with Oregon's Endangered Species Act programs on state lands and provide an incentive for conservation planning. To the extent that the recovery plan and the state Endangered Species Act programs can be made consistent, coordination between them will be improved.

There is very little state land within the area of special management emphasis, but on these lands the Oregon Department of Forestry is implementing a Sustainable Forestry Program on state lands that would yield additional benefits to wildlife by providing more snags, down material, and riparian zone protection.

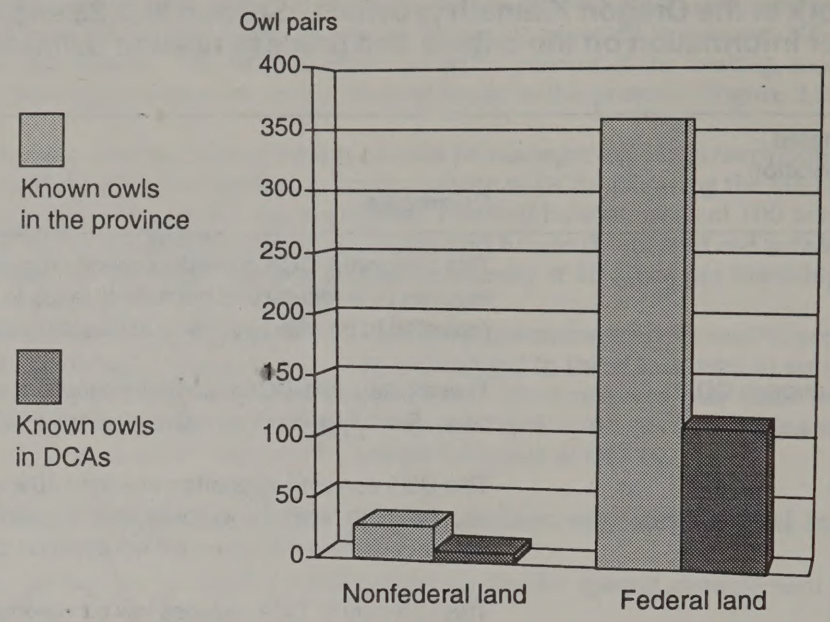


Figure 3.21. Known owl pairs in the Oregon Klamath province and in DCAs within the province.

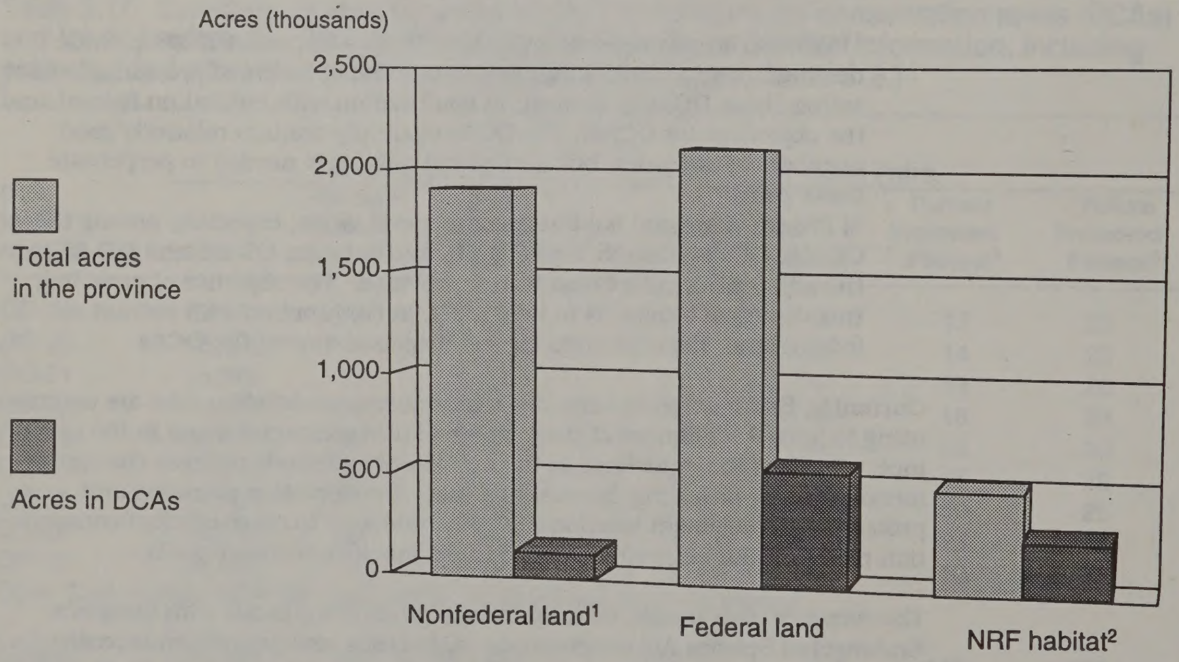


Figure 3.22. Acres in the Oregon Klamath province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

In checkerboard ownership areas where a federal nexus may exist, critical habitat designation could provide additional assurance of accomplishment of province recovery objectives. Federal land exchange or purchase might be necessary to meet these objectives in some areas.

The following province narratives for California are written in detail, to reflect current conservation planning efforts. Since December 1990, California landowners, forestry associations, environmental interests, scientists, and federal and state agencies have been participating in section 10 conservation planning (see section II.C.5.) The following descriptions of biological goals and implementation options are derived from the ongoing conservation planning efforts. The narratives also mention habitat conservation plans (HCPs) that have been, or are being prepared, by industrial forest owners in California.

California Coast Province

Province description

The California Coast province extends from the Oregon border to San Francisco Bay and from the ocean to the western border of national forest lands. The coastal portion of the province encompasses the majority of the redwood forest habitat type (Appendix B). Inland forests are Douglas-fir and mixed Douglas-fir/hardwood types, the latter often interspersed with chaparral and grasslands. Most forestland is in industrial or nonindustrial private ownership. Federal land in the province includes two national parks, a BLM conservation area, and a small portion of the Six Rivers National Forest.

The Round Valley Indian Reservation occurs within the California Coast province; recovery contributions by the Covelo tribes are described in section II.C.8.

Approximately 35 percent of the northern spotted owl's range and 30 percent of its known population in California are in the California Coast province. Owl populations are relatively high, with 450 known historic activity centers (11 percent on federal lands); pairs have been verified at 188 of these locations during the past 5 years.

Major threats in the province are the rate of habitat loss, particularly in the redwood zone, the low level of suitable Douglas-fir habitat, and the isolation of two populations at the southern end of the range of the subspecies (section II.B.6.).

Approximately 80 percent of the known spotted owl population in the province is on nonfederal lands. If those owls were extirpated, the remaining populations on federal lands would be too small and scattered to be self-sustaining. The spotted owl populations on federal lands south of northern Humboldt County likely would be extirpated, and this loss in turn would affect populations in the southern end of the adjoining California Klamath province, where owl density and amount of habitat are already low.

Biological goals and implementation on federal lands

Lack of federal land ownership in this province limits the recovery potential. As a result, no category 1 DCAs can be delineated in the province. However, 28 category 2 DCAs are recommended (Table 3.19., Table 3.20.). The larger DCAs are in national parks; the remaining DCAs are in the BLM conservation area and other BLM land. BLM parcels are included in smaller category 2

DCAs, often combined with adjacent state park lands. Eleven of these parcels might be consolidated into three groups, one of which could be a category 1 DCA. The DCAs contain approximately 50 percent of the owl pairs known to occur on federal lands in the province (Figure 3.23).

Table 3.19. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the California Coast province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J.9.)

	Acreage			Owl Pairs			
DCA Ident. Number	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
CD-47	32,388	42		1	0	2	3
CD-48	80,250	83		0	0	10	14
CD-50	38,455	84		2	0	10	12
CD-52	73,644	57		1	0	11	11
CD-53	8,306	47		0	0	2	2
CD-54	1,558	63		1	0	1	1
CD-56	2,272	100		3	0	3	3
CD-57	6,574	38		0	0	1	3
CD-58	1,266	90		0	0	1	2
CD-59	5,340	52		0	0	3	4
CD-60	2,899	58		0	0	1	3
CD-61	4,576	59		1	0	1	3
CD-62	2,676	52		0	0	1	2
CD-63	2,970	77		0	0	1	3
CD-65	10,676	91		1	0	1	2
CD-66	12,907	58		0	0	1	5
CD-67	8,090	53		0	0	0	2
CD-69	2,979	76		0	0	1	2
CD-70	2,555	63		0	0	0	1
CD-73	4,650	79		0	0	1	2
CD-74	7,715	91		0	0	1	3
CD-75	6,953	65		0	0	1	2
CD-76	1,069	100		0	0	1	1
CD-77	1,865	88		0	0	0	0
CD-78	2,500	36		0	0	1	1
CD-80	3,520	92		0	0	1	2
CD-201	43	100		0	0	1	0
CD-202	426	100		0	0	1	1
OD-22	This DCA crosses state boundary; data are illustrated in Oregon Klamath province table.						
Totals:	**329,122**	**69**		**10**	**0**	**59**	**90**
Totals for all lands in province:					**20**	**135**	

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for this province.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.20. Summary comments on the designated conservation area (DCA) network in the California Coast province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
CD-47, CD-48, CD-50, and CD-52	Limited federal land ownership does not provide opportunities to delineate category 1 DCAs. These category 2 areas are important for demographic support of the owl population in the northern California Coast Range. These DCAs also provide for population connectivity with interior DCAs on national forest lands.
CD-53, CD-54, CD-56 through CD-63, CD-65 through CD-67, CD-69, CD-70, CD-73 through CD-78, CD-80, CD-201, and CD-202	Many BLM parcels in the California Coast province are delineated as DCAs. Their size and distribution limits the ability of any parcel to support more than five pairs. Many of these small DCAs may not be able to support even a single pair of owls without additional suitable habitat on surrounding state or private lands. The value of these areas is to connect suitable habitats throughout the north coast area and to provide short-term demographic support and future nesting areas in conjunction with suitable habitat on private lands.

Southern Del Norte and northern Humboldt Counties. Federal lands in this area have too little habitat capability to support 20-pair clusters without support from nonfederal lands. DCAs CD-47 and CD-53 are expected to maintain fewer than three pairs each, but their owl populations could be strengthened by owl populations on nearby state and private lands.

Southern Humboldt and central Mendocino Counties. As in the rest of the province, federal land and state parks in this area are too small to support 20-pair clusters and should be supplemented by nearby lands with suitable habitat. Also, the category 2 DCAs and the residual habitat areas in this area should be supported by nonfederal lands to make them consistent with size, spacing, and density criteria. Three category 2 DCAs could be upgraded to support 20 owl pairs by consolidation with other DCAs and management areas on private lands. Dispersal habitat on federal and nonfederal land is needed among areas managed for owl clusters.

Biological goals on nonfederal lands

Minimum rangewide recovery goals for nonfederal lands are described in section III.C.4. With the lack of federal land, additional recovery goals for nonfederal lands in the California Coast province are to provide demographic stability and maintain northern spotted owl distribution throughout the province. This can be achieved by conservation measures that result in the equivalent of 11 clusters of breeding pairs appropriately spaced throughout the province, with adequate dispersal habitat among the clusters.

The continued presence of owls in this province depends upon state and private lands. Only 11 percent of the known owl sites in the province are on federal lands, and these sites alone are insufficient to maintain owls through-

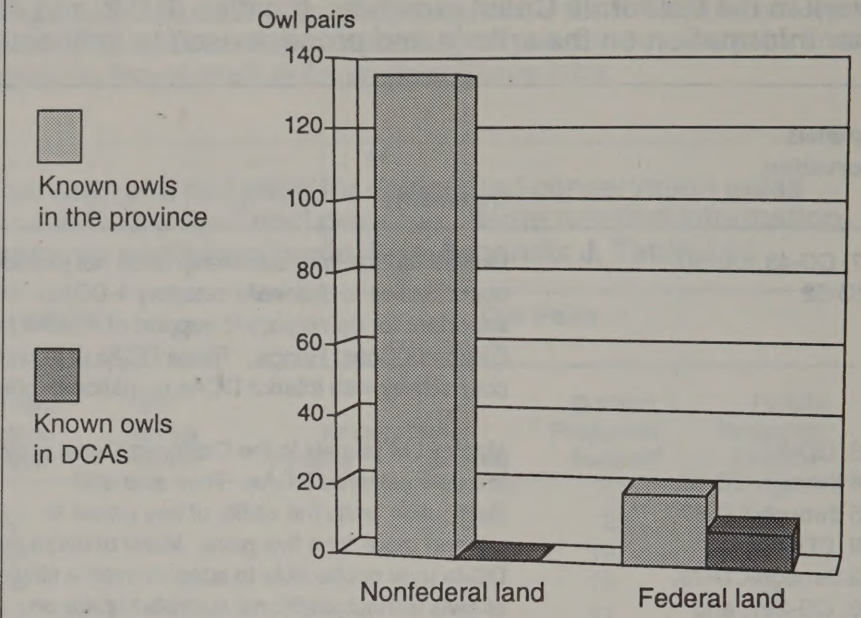


Figure 3.23. Known owl pairs in the California Coast province and in DCAs within the province.

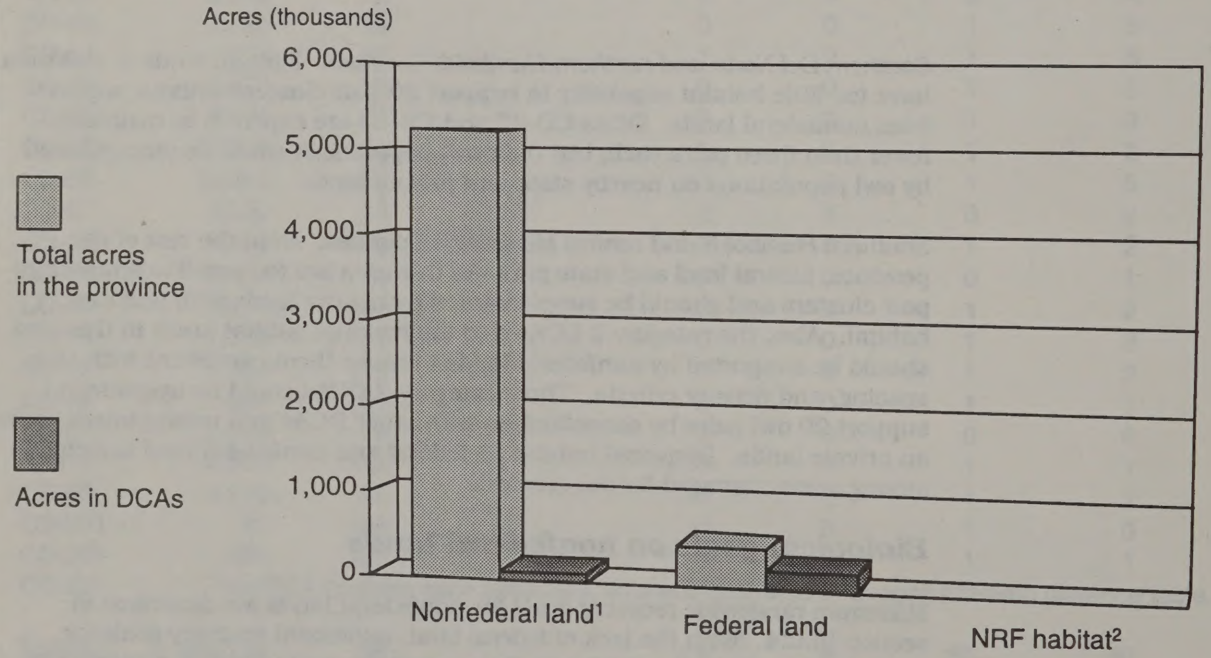


Figure 3.24. Acres in the California Coast province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is not available for this province.

out the province. These owl activity centers on federal lands contribute to four of the 11 larger clusters needed to maintain the owl population throughout the province. Outside of the Redwood National Park areas, owl activity centers on federal land will contribute no more than 11 owl pairs to any of the clusters on nonfederal lands. Also, distances among most of the DCAs on federal lands exceed current size and spacing standards, which creates more need for dispersal habitat on the intervening nonfederal land.

There is not enough habitat in the DCAs in this area to support a sustainable owl population. Options exist for nonfederal lands to supplement existing DCAs, and to provide for clusters where spacing among DCAs exceeds the current standards. Supplementing DCAs and providing for clusters does not require reserves or set-asides of private land and can be achieved through voluntary actions on private lands and compliance with regulations.

Del Norte and northern Humboldt Counties. Nonfederal lands can be managed for nesting, roosting, and foraging habitat, for clusters or supplemental pair areas, and for dispersal habitat among owl clusters and DCAs.

Central Humboldt County. A substantial population of spotted owls occurs east and southeast of Eureka, but no DCAs are possible in this area. At least two 20-pair clusters or equivalent supplemental pair protection would be needed on state and private lands in this area to meet recovery goals for demographic stability and distribution throughout the province. Dispersal habitat should be maintained among areas managed for owl clusters.

Southern Humboldt and northern Mendocino Counties. DCAs and state parks are too small in this area to hold 20-pair clusters and must rely on other nearby lands with suitable habitat to provide demographic support. All category 2 DCAs and residual habitat areas would benefit from support by supplemental pair areas or habitat on state and private lands, as feasible and consistent with current size and spacing criteria. At present, approximately 25 category 2 DCAs and 10 residual habitat areas in this area are on federal land and would benefit from this support. For example, three category 2 DCAs have the capability to be upgraded to support 20 owl pairs by combining them with other DCAs and instituting favorable management on private lands. Fourteen owl activity centers on state park lands also would benefit from this type of supporting habitat. In addition to providing nesting, roosting, and foraging habitat, dispersal habitat is needed among areas managed for owl clusters and DCAs.

Southern Mendocino to northern Sonoma Counties. Two 20-pair owl clusters are needed in this area to support owl populations farther south and east in Sonoma, Napa, and Marin Counties. The clusters would be best placed in the generally suitable habitat near the coast; habitat of naturally low suitability is found west and southwest of Clear Lake. Adoption of standard spacing among clusters would result in locating one in southwestern Mendocino County and one in northwestern Sonoma County. One state park could serve as the basis for a cluster, supported by management for additional pairs on private land.

Southern end of the province. Owls in the southern part of the California Coast province have the highest risk of extirpation because of their isolation. Habitat in northern Marin County, northeastern Sonoma County, and most of Lake County is either unsuitable, or is of low or questionable suitability. Owls may not disperse readily across these areas. Three state parks in this area are large enough to serve as the basis for three breeding clusters, if augmented by private lands. However, it may not be feasible to support 20 owl pairs in these breeding clusters. Known owl activity centers on state and private lands in these breeding clusters should be managed conservatively to retain all owl

nesting and roosting habitat until monitoring and research indicate that the threat of local extirpation has been diminished substantially.

Implementation options on nonfederal lands

Several options are available for achieving recovery goals on nonfederal lands in the California Coast province. There are a number of existing reserves, including federal lands and state parks. Most of the state land in the province is in two parks and can be expected to provide owl habitat over the long term.

Managed forests on private lands also can provide for nesting, roosting, foraging, and dispersal habitat. The potential for finding additional owls through surveys is high, and may create an incentive for private landowners to develop landscape management approaches for owl conservation. At least one large industrial landowner is developing a habitat conservation plan (HCP), and other landowners have expressed interest in developing an HCP or other habitat conservation measures.

State forest practices rules and the state-sponsored HCP process provide other avenues for landscape management. Current take prohibitions do not provide directly for adequate clustering of owl pairs or spacing of owl clusters, because the state forest practices rules place constraints on cumulative impacts, activity in riparian zones, and the size and spacing of clear-cuts. Amendments to the forest practices rules would be needed to require specific habitat retention standards, different "zonal" practices, and long-term plans. The forest practices rules currently provide for long-term plans only on nonindustrial ownership. The state-sponsored HCP program is addressing these issues and is expected to be completed in early 1993.

Land acquisition opportunities are expected to be limited because of the lack of federal lands available for exchange, lack of funding for purchase, and concerns regarding removing land from private ownership.

There are potential implementation difficulties in northern Marin, northeastern Sonoma, and Lake Counties because of habitat and ownership patterns. Owl conservation in this area may have to rely on take prohibitions on a case-by-case basis. The ability to maintain owl populations is limited by poor suitability and distribution of habitat, numerous small ownerships, and the inability to manage landscapes collectively. Existing local land trusts and open-space districts may provide funds for land acquisition but probably will require active participation of county government through local land-use regulation.

Implementation of recovery goals would be expedited if landowners were given flexibility in the placement of clusters, although this approach may require greater monitoring efforts and conservative targets.

Three options are presented for achieving recovery goals, however, other options may be appropriate if they achieve equivalent or better protection for the owl. Given the variation in land ownership and specific conservation needs throughout the province, a combination of options is likely to be implemented eventually. Each option must be evaluated by its ability to achieve recovery goals if fully implemented.

Option 1: Management of individual owl sites

This option would build clusters of owls based on current knowledge of owl sites. Clusters would be identified in a specific location, quantity, and quality of habitat.

This option would provide the opportunity for timber management on private lands that includes clusters or support DCAs and reserved pair areas while meeting standards for suitable habitat quality and quantity. Managing to maintain dispersal habitat is recommended for private lands among DCAs and owl clusters on private lands. In northern Marin, northeastern Sonoma, and Lake Counties, concerns about low population and connectivity to the adjacent province would preclude timber harvest of suitable owl habitat.

Habitat requirements for individual sites could be identified by implementing minimum stand structure provisions for each habitat type within this province. On private lands, owners could manage owl habitat if safeguards ensured the maintenance of local owl populations. Safeguards could take the form of performance bonds, mitigation banks, or dedicated areas such as easements.

Implementation and monitoring under this option would require substantial owl surveys. Consequently, this option, compared to other options, may be harder to establish because of management on a site-by-site basis. This option would provide landowners with the least amount of management flexibility at the site level and may raise equity issues among ownerships. Private landowners who have conducted owl surveys on their lands may have a disadvantage over those who have not surveyed for owls when known owl sites are used to establish clusters.

This option, compared to the other two options, may be easier to monitor for compliance, and would allow site-specific management practices tailored to site-specific conditions. The site-by-site application may make it easier to review the impact of management practices. Protecting known nest sites within a larger landscape strategy of clusters and dispersal habitat may present lower risk to owl populations over the short term.

Option 2: Management of clusters: fixed boundaries

This option would allow for management at the 20-pair cluster level, in lieu of the individual site level. Clusters would be located with fixed boundaries, and habitat quality and quantity within the cluster would be managed to support a specified number of owls. Other standards (e.g., minimum habitat block size, spacing of habitat blocks) would be provided. Location of owl sites within the cluster may be more variable over time than in option 1. The cumulative impact of timber harvesting and other forest management activities on owl habitat within the cluster would be evaluated, and mitigation measures could be proposed to offset the impacts. Owl clusters in the southern extreme of the province would be managed to retain all suitable habitat.

Habitat standards and safeguards would be similar to those in option 1. Since fixed boundaries for supporting DCAs and clusters on private lands are recommended, implementation could rely on known existing owl sites or additional owl survey work. Once cluster areas are established, monitoring habitat conditions over time would be more important than individual owl surveys. This option would provide greater flexibility to landowners than does option 1 and allow for local management options.

This option also would require a higher level of habitat monitoring and perhaps greater amounts of habitat than would option 1, because the status of owl pairs is not stressed. If long-term monitoring determines that forest management achieves expected results in owl populations, a longer time or greater conservation action may be required to correct the strategy.

Option 3: Management of clusters: general boundaries

This option would allow greater flexibility to private landowners in meeting recovery objectives because the boundaries of areas managed for owl clusters are generalized. Each cluster would have a designated general size, based on the numbers of owls it should contain and the home range size that would be necessary for owls in that province. Only a general location would be specified to meet spacing guidelines; the location of the perimeter would not be fixed. Guidelines would be based on maintaining owl pairs in clusters rather than maintaining isolated owl pairs or individuals. Landowners would determine where owls would occur within clusters. An owl cluster within a single landownership would be managed by the landowner. An owl cluster that encompasses land owned by several landowners would be managed through a coordinated resource management plan agreed upon by all landowners. Owls in the extreme southern portion of the range would be managed in enlarged clusters with no removal of owl nesting and roosting habitat.

This option would provide the landowner with the greatest number of options in land management and would require minimal owl surveys. Owl surveys could be limited to those required to estimate population trends for the province. The option also could serve as the framework for a more generalized, landscape-based habitat conservation strategy that could consider other species, biological diversity, and ecosystems.

This option would require substantial management planning by landowners to ensure that recovery goals will be achieved and maintained. Habitat monitoring would be the paramount concern and would be the responsibility of landowners and implementing agencies. This strategy also would carry a higher risk of declines in owl populations during the short term or delays in meeting recovery goals, since many of the relationships between owls and forest management over the long term are unclear at this time and have not been tested.

Achieving recovery goals for the province will require strong coordination among large and small private landowners, the state, and the state forest practices rules. In many areas the need for BLM participation will be high because of the numerous small BLM parcels adjacent to state and private lands. In Marin, Sonoma, and Napa Counties, coordination with local and county governments may be critical to maintain owls on private lands and to use zoning to help maintain owl habitat. Coordination in managing owls in this province is underway in the form of a state-sponsored habitat conservation plan (HCP) for the northern spotted owl in California.

California Klamath Province

Province description

The California Klamath province is located between the California Coast and the California Cascades provinces. It is a continuation of the Oregon Klamath province, south to the Clear Lake Basin in the inner Coast Range. The area is mountainous and covered primarily with Douglas-fir forests. Mixed Douglas-fir forests are common at lower elevations with Douglas-fir/true fir forests at higher elevations. The province land ownership is dominated by four national forests, but includes a few parcels of BLM lands near the eastern border. There are some private forestlands, also near the eastern edge of the province.

The Hoopa Indian Reservation occurs within the California Klamath province; recovery contributions of the Hoopa Tribe are described in section II.C.8.

There are 950 historic owl activity centers in the California Klamath province, 88 percent of which are on federal lands. During the 1986-90 period, pairs of owls were identified at 455 of these sites. Eighty-eight percent of these pair activity centers occur on federal lands.

The major threats to the northern spotted owl population in this province arise from reduction in suitable habitat and resulting loss of owls caused by timber harvesting during the last 40 years. Catastrophic fires occur within the province and have the potential to destroy forested areas large enough to support a 20-pair cluster.

Spotted owls in this province are important to maintain genetic contact between the northern spotted owl and California spotted owl subspecies. Genetic contact is thought to be important because of the low numbers and scattered distribution of owls in the California Cascades province, and recommended DCAs reflect that concern.

Biological goals and implementation on federal lands

Fourteen category 1 and 19 category 2 DCAs are recommended in the province (Tables 3.21 and 3.22). All category 1 DCAs occur in the western and northern part of the province, providing the demographic stability for owl populations in the province. The category 1 DCAs include little state or private land; these nonfederal lands support few owls and are not essential for demographic stability. Large DCAs in the northern and western portions of the province have better natural site conditions and higher known owl populations than do the eastern and southern portions of the province. The presence of theses DCAs reduces the need for contributions from state and private land in the western portion of the province.

Category 2 DCAs are common along the eastern edge and the southern end of the province. Twelve reserved pair areas will be needed in the southern end of the province where category 2 DCAs are deficient in suitable habitat, and along the eastern edge of the province where spacing requirements among DCAs cannot be met.

The DCAs contain 52 percent of the owl pairs and 41 percent of the nesting, roosting, and foraging habitat on federal land in the province (Figures 3.25 and 3.26).

Outside of the DCAs, federal lands should be managed under matrix prescription A.

Biological goals and implementation options on nonfederal lands

Scientific goals for nonfederal lands in the province are to provide for local demographic support and maintain distribution across the province and between this province and the California Cascades province. Given the dominance of federal land ownership in the province, there is no need for local population clusters on state and private lands in the western zone. Recovery will be enhanced by supporting existing DCAs in the eastern and southern zones with additional pairs from private lands, and by managing for a new cluster on state, private, and BLM lands in eastern Trinity County.

Achieving the recovery goals for nonfederal lands in this province would contribute substantial support to the demographic stability of owl populations within the province, and increase the likelihood of more rapid recovery. Dispersal sinks, which negatively affect overall population stability, could result if

Table 3.21. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the California Klamath province. (More detailed information, including projected owl pairs on nonfederal land is in Appendix J, Table J.10.)

DCA Ident. Number	Acreage			Owl Pairs			
	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
CD-1	104,956	99	42,240	7	0	27	28
CD-2	55,596	99	26,040	9	0	21	23
CD-3	38,032	95	14,200	27	0	28	25
CD-4	62,989	95	35,840	16	0	22	25
CD-5	83,065	100	14,960	8	0	25	29
CD-6	47,559	100	13,000	10	0	20	22
CD-7	14,171	96	1,840	7	0	6	8
CD-8	140,630	100	71,280	23	0	42	44
CD-9	6,299	100	2,120	1	0	2	2
CD-10	56,011	95	17,520	13	0	21	23
CD-11E	97,567	98	27,600	9	0	22	24
CD-11W	95,908	99	44,320	12	0	26	28
CD-12	54,928	95	17,400	8	0	21	23
CD-13	43,795	91	24,080	7	0	16	20
CD-14	30,042	91	4,040	4	0	5	7
CD-15	112,694	98	34,480	12	0	29	31
CD-16	66,371	98	13,680	6	0	22	24
CD-17	33,597	97	6,000	3	0	6	7
CD-18	50,221	97	8,600	2	0	9	14
CD-19	27,563	88	5,520	4	0	5	6
CD-20	9,758	93	1,880	4	0	3	3
CD-21	25,743	98	5,440	2	0	5	7
CD-23	7,145	99	2,760	2	0	4	4
CD-24	3,383	100	1,360	1	0	1	1
CD-25	4,218	99	1,680	1	0	1	1
CD-26	1,716	54	360	1	0	1	1
CD-27	2,262	83	480	1	0	1	1
CD-29	23,613	95	4,960	2	0	6	7
CD-30	13,187	85	3,000	1	0	3	4
CD-31	40,191	78	7,840	3	0	8	15
CD-32	9,811	71	2,280	3	1	2	3
CD-33	4,133	96	760	0	0	0	2
CD-34	3,138	78	240	1	0	1	2
OD-20	This DCA crosses state boundary; data are illustrated in Oregon Klamath province table.						
Totals:	**1,370,292**	**96**	**457,800**	**210**	**1**	**411**	**464**
Totals for all lands in province:				**1,105,550**	**403**	**52**	

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions. See Appendix J for further details.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.

Table 3.22. Summary comments on the designated conservation area (DCA) network in the California Klamath province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
CD-3 and CD-8,	These category 1 DCAs each currently support 20 or more pairs of owls.
CD-1, CD-2, CD-4 CD-5, CD-6, CD-10, CD-11E, CD-11W, CD-12 CD-13, CD-15, and CD-16	These category 1 DCAs currently support fewer than 20 known pairs of owls. With the exception of CD-13, they all have the current potential to support at least 20 pairs. All of them have the future potential to support at least 20 pairs.
CD-7, CD-9	These DCAs do not support 20 pairs. CD-9 provides connectivity around a high-elevation wilderness area. DC-7 provides connectivity to DCAs father east.
CD-14, and CD-17 through CD-21	This drier and naturally fragmented habitat will support from 3 to 15 pairs in the future.
CD-23 through CD-27, CD-32 through CD-34	Because of the naturally fragmented landscape, larger multipair DCAs are not possible. These DCAs provide connectivity to DCAs to the west and provide the link between the ranges of the northern spotted owl and the California spotted owl in the Sierra Nevada.
CD-29 and CD-30	No opportunities exist to support Category 1 DCAs. DCAs are delineated where owls are currently known, future habitat opportunities occur, and where the only demographic support for this local population is possible. Suitable habitat is not uniformly distributed over this region because of moisture and soil conditions.

nonfederal lands are not managed to support the federal conservation efforts. Increases in demographic support assist in maintaining the linkage between the California Klamath and the California Cascades provinces, and support populations in the adjacent California Cascades province as well. his linkage could be crucial to maintaining the owl population in the California Cascades province. Maintaining strong populations of the northern spotted owl in the California Klamath and Cascades provinces also would help maintain the linkage to the California spotted owl.

Western zone: No additional owl clusters or DCA support for owls are needed on state and private lands in the western part of the province, other than management for dispersal. DCAs on federal land should be consolidated through the inclusion of inholdings.

Eastern and southern zones: The eastern and southern parts of the province are drier and support a lower known population of owls, reflected by the lack of category 1 DCAs. At least six category 2 DCAs and three reserved pair areas could be supported with currently known sites on state and private lands. Although this probably would not result in upgrading to category 1, it would increase the stability of the relatively small owl populations in these clusters.

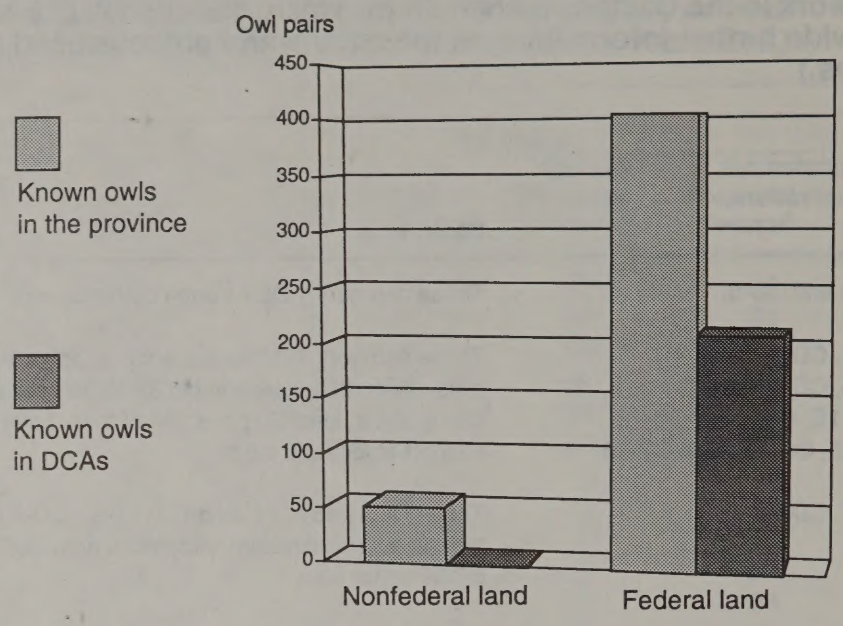


Figure 3.25. Known owl pairs in the California Klamath province and in DCAs within the province.

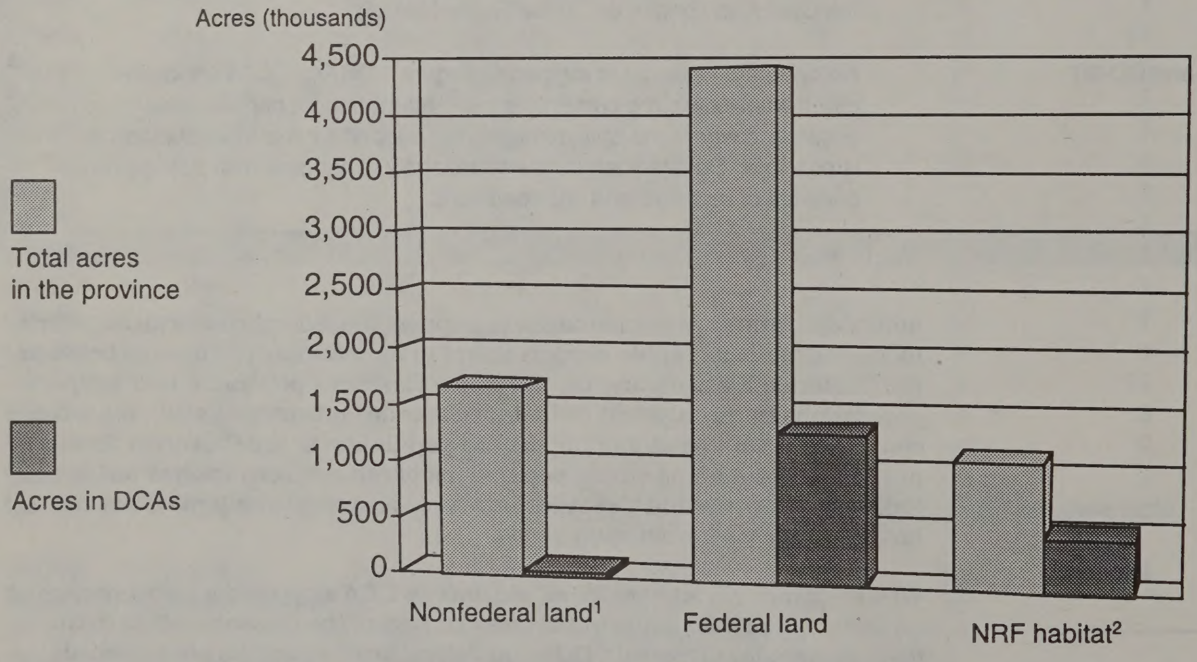


Figure 3.26. Acres in the California Klamath province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

Managing for a new cluster on state, private, and BLM lands in eastern Trinity County would enhance recovery. This cluster would provide stronger demographic support in this part of the province and better connectivity across the southern end of the Trinity Alps to the California Cascades province.

Implementation options on nonfederal lands

Numerous alternatives exist for achieving recovery goals on nonfederal lands in the California Klamath province. There are substantial reserves of public lands, and the recommendations for federal DCAs incorporate most of them. One large private timberland owner has committed to a management plan incorporating extensive owl surveys to ensure that owls will not be taken as a result of the landowner's timber operations. A number of other timberland owners in the province voluntarily practice partial entry or uneven-age management which lessens impact to owl habitat. Other timberland owners have expressed an interest in developing comprehensive owl management plans for their ownerships, in compliance with the current state forest practices rules. The large number of owl sites in the area is an incentive for developing these plans, as is the state-sponsored HCP, which could benefit smaller acreage landowners in the province.

Forest practices rules would have to be amended to require specific habitat retention standards, different practices in different "zones," and long-term plans. Forest practices rules currently provide for long-term plans on nonindustrial ownerships only. The state-sponsored habitat conservation plan (HCP) is underway and addressing these issues. The HCP is expected to be completed in early 1993.

The extensive checkerboard ownership pattern in the province offers greater flexibility to explore land exchanges.

Land acquisition is likely to be less attractive, since many of the timberland owners also own processing facilities that depend on a stable timber base.

The feasibility and likelihood of early implementation of actions to achieve the recovery goals will increase if landowners are given greater flexibility to designate areas for maintaining nesting, roosting, and foraging habitat for supporting DCAs, but this may require greater effort in monitoring and establishment of more stringent initial objectives.

Four options are presented for achieving recovery goals. The options are not exhaustive, and other options may be appropriate if they achieve equivalent or better protection for the owl. Other options might provide for more general landscape level habitat management, protection for other species and long-term management. Given the differences in land ownership and specific conservation needs throughout the province, it is possible that some combination of the options eventually will be implemented. All options must be evaluated based on the likelihood that they will achieve recovery goals when fully implemented.

Option 1: Management of owl sites adjacent to federal DCAs

This option would consolidate DCAs on federal land through the inclusion of inholdings in the western zone. Inholdings would be managed to create and maintain suitable owl habitat. The option would offer nonfederal support to category 2 DCAs and reserved pair areas in the eastern and southern zones, using sites less than, or equal to, 3 miles from the current DCA boundary, and all sites within the DCA boundary. Sites used for supporting federal areas would have specified locations (e.g., confine site location to a specific drainage

and to within 0.5 miles of the activity center), and rules that would ensure that the appropriate quantity and quality of habitat be maintained. Dispersal habitat also would be designated throughout the province. A 20-pair cluster in eastern Trinity County would be managed with fixed boundaries and locations of sites.

Extensive surveying for owls would be necessary to implement this option and monitor it over time. Fixed boundaries and site locations increase the certainty during the short term that owls will be found, but may raise issues of equity between landowners. Unless the area has been extensively surveyed, the use of existing known sites as the basis for restricting management may effectively penalize those owners who have conducted surveys and are engaged in active research. This option limits the flexibility of landowners with the responsibility of providing for owl sites.

Option 2: Management of owl sites at the watershed level

This option would provide a management strategy to maintain dispersal habitat on private inholdings within federal DCAs in the western zone, but would create incentives for consolidating the inholdings with DCA management. It would provide nonfederal support for category 2 DCAs and reserved pair areas in the eastern and southern zone, using lands within the general watershed areas containing the DCA. Sites would be distributed based on known owl occurrence. Owl sites within the major watersheds currently encompassed by the DCA would be recommended to provide support for the DCA. These sites would be managed to ensure that the appropriate quantity and quality of suitable habitat would be maintained and that the location would be maintained (e.g., similar to current state forest practices rules regarding take, and confine the site activity center to a 3,000-acre area within a specific drainage). Dispersal habitat would be maintained throughout the province. A cluster of 10 pairs is an objective for eastern Trinity County.

This option provides somewhat more flexibility to private landowners. It is still based on managing for individual activity centers, so extensive owl surveys would be required. The location of sites is more flexible than under option 1, and fewer sites are likely to be required throughout the province. Higher risks may be associated with maintaining only dispersal habitat on inholdings within DCAs in the western zone. Implementing this option, which is based on currently known activity centers, may effectively penalize landowners who have surveyed extensively for owls, unless the area has been extensively surveyed.

Option 3: Management of all known owl sites

This option would maintain dispersal habitat on private inholdings within DCAs in the western zone, but would create incentives for consolidating the inholdings with DCA management. Nonfederal land would support category 2 DCAs and reserved pair areas in the eastern and southern zone, using all known sites. Habitat requirements for individual activity centers could be identified and managed by implementing minimum stand structure provisions for each habitat type within province. Additionally, guidelines would be provided at the cluster level to maintain such characteristics as the percentage of suitable habitat in the cluster, the minimum stand size and distribution of that suitable habitat, and the presence of high-value habitat at the activity center. Dispersal habitat would be designated throughout the province.

This option also would include establishing a new cluster on state, private, and BLM lands in northeastern Trinity County. This cluster has the potential for 20 activity centers. Habitat would be provided by prescriptive management rules controlling the quantity and quality of habitat to be maintained. It would

confine site location to a specific drainage and would be within 0.5 miles of the activity center.

This option would provide the best demographic support for the populations in these areas where habitat conditions preclude maintaining large enough clusters to provide a good chance of maintaining a viable population over time. Over time this might result in forming larger clusters than currently possible and in increasing local population stability.

This option would require extensive owl surveys to identify owl sites and to monitor implementation. The option creates a disincentive to locate owl sites and an incentive to harvest suitable but unoccupied habitat. Management strategies for areas where spatial distribution of known locations do not "match" with needs to support DCAs.

Option 4: Landscape-based habitat management

This option would require maintaining dispersal habitat on inholdings within DCA boundaries in the western zone, but would provide incentives for maintaining nesting, foraging, and roosting habitat. Category 2 DCAs and reserved pair areas in the eastern and southern zones would be supported by providing suitable habitat in areas within major watersheds included within DCA boundaries. Specific location of suitable habitat for activity centers would not be specified, but quantity and quality would be ensured at the watershed level. Suitable habitat to support 10 pairs of owls would be maintained in eastern Trinity County, using existing federal lands as the basis. Specific owl site locations and cluster boundaries would not be designated.

This option provides greater flexibility to the private landowner. It would not require owl surveys to the extent of other options. The option provides incentives for landowners to participate in landscape level management, and to locate owls or manage habitat in desirable locations.

Coordination. Land ownership is dominated by the national forests. Private lands in the province are primarily large industrial forest holdings. BLM lands constitute a small but relatively important portion of the area where management of a cluster is proposed among multiple owners.

This option requires coordination between large industrial forest landowners and the state and its forest practices regulation mechanism. A state-sponsored habitat conservation plan (HCP) for the northern spotted owl in California is being drafted that will provide the coordination necessary to accomplish management suggested by this option.

California Cascades Province

Province description

The California Cascades province is located in the center of the north end of the state, between the Oregon Cascades province, the Klamath provinces, and the range of the California spotted owl at the north end of the Sierra Nevada. Suitable owl habitat generally is fragmented on a broad scale by the Shasta Valley, Mt. Shasta, and other high elevation areas, areas of unsuitable soils, and areas of marginal, low elevation habitats. Suitable forest habitat is predominately on two national forests although there are significant blocks and checkerboard ownership areas where forests occur on mostly industrial private lands. This area forms the linkage between the range of the northern spotted owl and the range of the California spotted owl.

Spotted owls have been found at 86 sites in the province; pairs have been verified at 34 of these in the last 5 years.

The major threats to this northern spotted owl population are its low numbers and density, and the fragmentation of the habitat that keeps pairs from aggregating and forming stable demographic units. Also, habitat conditions tend to isolate the populations inside the province from one another and from populations in neighboring provinces.

Low population numbers, low amounts of suitable habitat, and poorly distributed suitable habitat limit the contribution to recovery that historically and naturally can be expected from the California Cascades province. The population is at high risk for local and even province-wide extinction.

Minimum rangewide recovery goals for nonfederal lands are described in section III.C.4. Additional goals for nonfederal lands in the province are to provide substantial demographic support to DCAs, maintain owl distribution, maintain the connection between northern spotted owls and California spotted owls, and maintain all known and future sites on nonfederal lands.

The objectives for this province are considered important to maintaining the link between the two subspecies of the spotted owl in California. Providing local demographic stability to the province, with owls well distributed, is necessary to maintain the link. The value of the contact may be the genetic interchange between the two subspecies. This exchange is not likely if there are no northern spotted owls between the Sacramento River (north of Redding) and the California spotted owls at the northwest edge of Lassen National Forest.

However, the northern spotted owl population and habitat conditions in this area are such that the likelihood of achieving a province population size with a relatively low risk of extinction is not great. This, coupled with the lack of information on the northern spotted owl's historical occupancy of the province and the small population size, reduce the importance of the owls in this province to the rangewide preservation of the northern spotted owl subspecies.

Biological goals and implementation on federal lands

Twenty-three DCAs are recommended in the province (Table 3.23). Because the owl population in the province is small and dispersed, none of these will likely contain 20 or more pairs of owls and only one of the category 2 DCAs will likely contain more than ten pairs. Two reserved pair areas are recommended in the province between CD-108 and CD-109. The DCAs contain 92 percent of the owl pairs and 61 percent of the nesting, roosting, and foraging habitat known on federal lands in the province (Figures 3.27 and 3.28).

Remaining federal lands in this province should be managed under matrix prescription B.

Biological goals on nonfederal lands

Unless owls on state and private lands are managed to complement the owl population on federal lands, the benefits of conservation efforts on federal lands will be limited and the link between the two subspecies will likely be lost over time.

Implementation options on nonfederal lands

Because of the particular threats to the northern spotted owl in the California Cascades province, relatively few options are available for achieving recovery goals. Although a number of tools are available, conservation over the short term must focus on individual owl sites to offset the low population levels and poor distribution of suitable habitat.

Achieving recovery goals in this province will be potentially difficult. Existing reserves and DCAs may not have sufficient amounts of suitable habitat within them. Currently practiced partial entry and uneven-aged management may be amenable to modification to provide suitable habitat, and there is the possibil-

Table 3.23. Summary of acreage and owl pairs for designated conservation areas (DCAs) and for all lands in the California Cascades province. (More detailed information, including projected owl pairs on nonfederal lands, is in Appendix J, Table J.11.)

	Acreage			Owl Pairs			
DCA Ident. Number	Total	Percent Federal Land[1]	NRF Habitat Federal[2]	Known Owls[3] Federal	Known Owls[3] Nonfed	Current Projected Federal[4]	Future Projected Federal[5]
CD-28	41,356	83	5,240	7	0	5	7
CD-35	13,992	95	2,160	0	0	1	2
CD-36	2,133	98	1,040	0	0	0	0
CD-37	5,710	99	240	1	0	1	2
CD-38	9,982	96	2,560	0	0	1	3
CD-39	3,722	99	880	0	0	0	0
CD-40	2,419	91	640	1	0	1	1
CD-41	3,600	87	1,200	1	0	1	1
CD-42	70,985	91	22,920	5	0	10	12
CD-43	14,442	94	1,120	2	0	3	4
CD-44	11,095	94	2,920	2	0	2	3
CD-45	38,644	55	3,840	1	0	4	5
CD-101	1,913	93	—	0	0	1	1
CD-102	3,032	93	400	0	0	1	1
CD-103	2,699	98	40	1	0	1	1
CD-104	2,881	47	440	0	0	1	1
CD-105	1,267	88	240	0	0	1	1
CD-106	1,994	100	800	0	0	1	1
CD-107	2,880	96	2,240	1	0	1	1
CD-108	2,560	97	240	1	0	1	1
CD-109	1,910	88	200	0	0	0	0
CD-110	2,881	100	640	0	0	1	1
CD-111	2,881	90	320	0	0	1	1
Totals:	**244,978**	**85**	**50,320**	**23**	**0**	**39**	**50**
Totals for all lands in province:			**82,240**	**25**	**9**		

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF = nesting, roosting, and foraging habitat for spotted owls. Habitat information was not available for nonfederal lands.
[3]Numbers are pairs of spotted owls verified in a 5-year period either 1986 through 1990 or 1987 through 1991.
[4]This is an estimate of the number of pairs of owls that the DCA would be expected to support on federal lands if the population stabilized with current habitat conditions.
[5]This is an estimate of the number of pairs of owls that the DCA might support in the future on federal lands if habitat were recovered. See Appendix J for further details.
Dash (–) = data not available.

Table 3.24. Summary comments on the designated conservation area (DCA) network in the California Cascades province. (Section III.C.2. and Appendix I provide further information on the criteria and process used to delineate these areas.)

Designated Conservation Area	Comments
CD-35 through CD-41, CD-101 through CD-111	Because of the naturally fragmented landscape, larger multipair DCAs are not possible. These DCAs provide connectivity to DCAs to the west and provide the link between the range of the northern spotted owl and the California spotted owl in the Sierra Nevada.
CD-28, CD-42 through CD-45	No opportunities exist to support category 1 DCAs. DCAs are delineated where owls are currently known, where future habitat opportunities occur, and where the only demographic support for this local population is possible. Suitable habitat is not uniformly distributed over this region because of moisture and soil conditions.

ity of individual HCP or no-take plans. The scarcity of owls may not make landscape management attractive to landowners, especially if few owl sites are detected through no-take surveys. Forest practice rules do not provide for permanent protection of nest sites if they become unoccupied, and the rules would have to be amended. Habitat on state and private land could be obtained by purchase or land exchange. There is some potential for land acquisition, due to checkerboard ownership, but land acquisition likely would alter radically timber supply access among different owners. Land purchase is likely to be expensive, and landowners are likely to be concerned about removing land from private ownership, given the need for a timber base to supply existing mills.

Short-term deferral of harvest, until a long-term management strategy with low risk to the population can be drafted, might be accomplished through tax exemptions or habitat conservation easements, but the institutional mechanisms for accomplishing this are not yet developed.

One option is presented for achieving recovery goals. Other options may be appropriate if they achieve equivalent or better protection for the owl. All options must be evaluated based on the likelihood that they will achieve recovery goals when fully implemented.

Option 1: Manage existing owl sites to establish clusters

This option would include all currently known owl sites on nonfederal lands, and any new sites found in the next few years of intensive surveys, as supplemental pair areas. This would increase the demographic stability of the province over the short term. In the short term, existing suitable habitat would be retained, even if a site becomes unoccupied. Attempts should be made to combine sites on federal, state, and private lands into clusters of mutually supporting owl pairs. Future evaluation would have to be made to determine if larger clusters could be designated and maintained in a pattern that would provide a lower risk of future local extinction. Combining with other sites may not be feasible for some areas that will remain as reserved pair areas due to

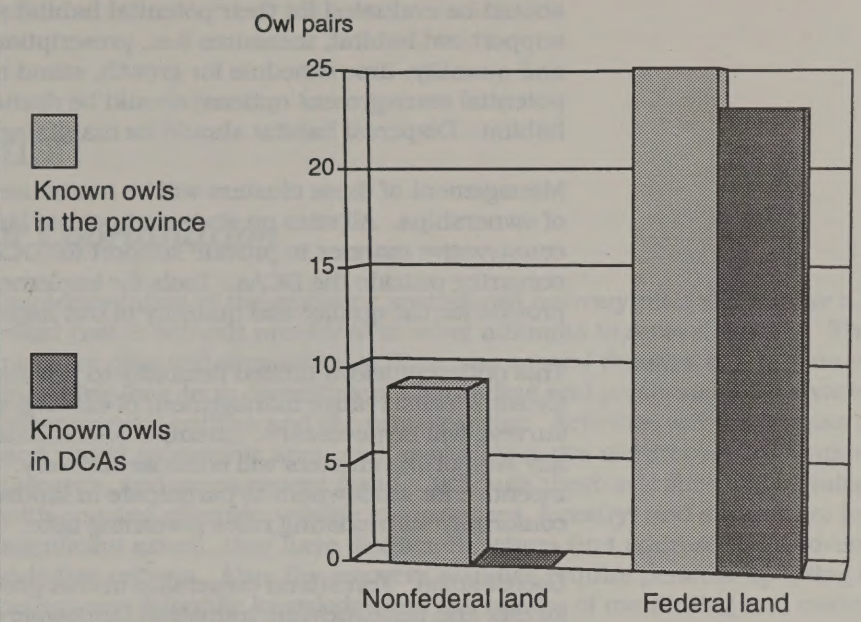


Figure 3.27. Known owl pairs in the California Cascades province and in DCAs within the province.

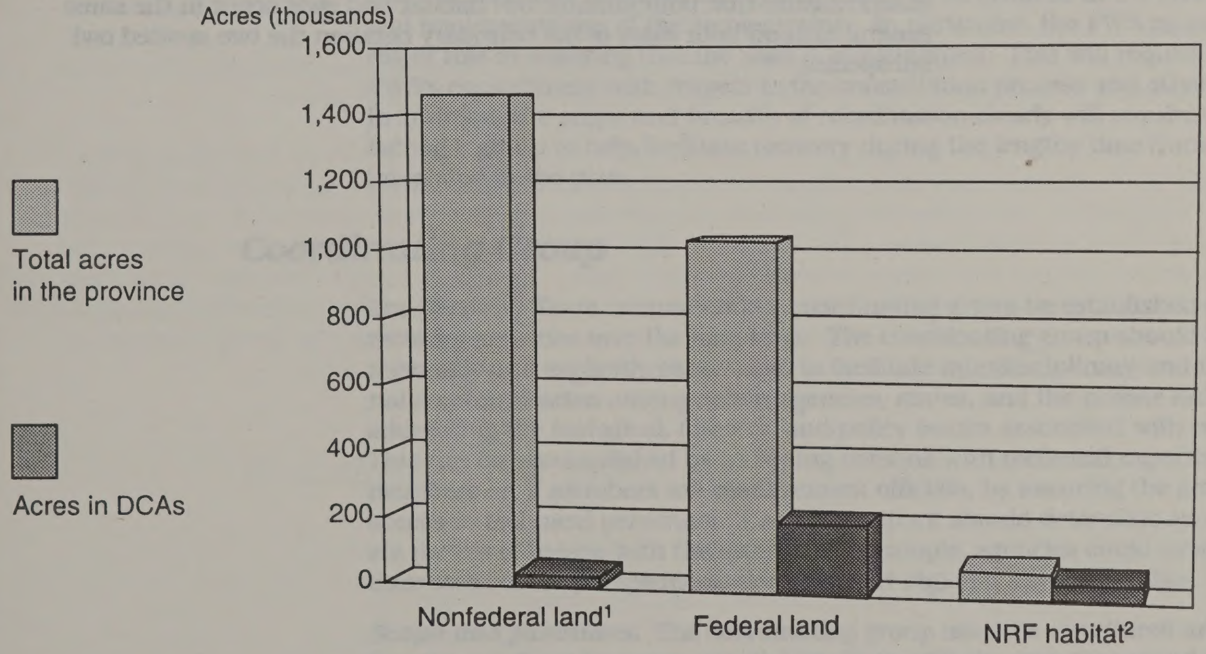


Figure 3.28. Acres in the California Cascades province and in DCAs within the province.

[1]Management of nonfederal lands within the perimeter of designated conservation areas is discussed in the narrative.
[2]NRF habitat = nesting, roosting, and foraging habitat. This information is available only for federal land.

their distance from other sites. Areas within clusters that do not have owls should be evaluated for their potential habitat suitability. If these areas can support owl habitat, measures (i.e., prescriptions for certain habitat quality and quantity, time schedule for growth, stand management requirements, and potential management options) should be drafted to guide creation of owl habitat. Dispersal habitat should be maintained throughout the province.

Management of these clusters will be a mixture of practices because of the mix of ownerships. All sites on state and private lands need to be managed in a conservative manner to provide support for DCAs and individual owl pairs occurring outside the DCAs. Tools for implementation include regulations that provide for the quality and quantity of owl habitat to be maintained.

This option provides limited flexibility to private landowners, but it does allow for some conservative management of existing suitable habitat. Extensive owl surveys will be necessary. Attempts to combine individual sites to form mutually supporting clusters will enhance recovery. This option provides little incentive for landowners to participate in landscape management or go beyond conformity with existing rules governing take.

Coordination. Forestland ownership in this province is dominated by national forests and large, private, industrial landowners. Only small amounts of other ownerships would be involved in maintaining local owl populations.

This option requires strong coordination among federal land management agencies and private landowners, and the state through its forest practices regulation mechanism. This process is ongoing and is being strengthened by the drafting of a habitat conservation plan (HCP) by the state. This plan should assure that both suitable owl habitat and owls occur in the same general area on both sides of the boundary between the two spotted owl subspecies.

5. Coordination

Need for Coordination

Implementation of the northern spotted owl recovery plan will require a level of effort that is without precedent in other attempts to recover species. The recovery plan will necessitate actions over several decades at a minimum, including long-term commitments of funding and personnel from a variety of governmental entities and the private sector. Activities will encompass a large and varied geographic area, and involve intensive monitoring, evaluation, research, and management tasks. Although these activities will be integrated with ongoing efforts in wildlife management, forestry, and silviculture to a significant extent, they have distinct objectives that address the recovery plan's delisting criteria. Also, the recovery plan will require periodic updating to reflect new scientific knowledge and the results of monitoring and evaluations.

Efficient and effective implementation of the recovery plan will require mechanisms to coordinate the wide variety of activities by the participating entities. In the short term, the Recovery Team should be maintained to provide that coordination function. Federal agencies (National Park Service, Bureau of Indian Affairs, Fish and Wildlife Service, Bureau of Land Management, Forest Service) and state government agencies need to be involved in the coordination and implementation of the recovery plan. In particular, the FWS must play a major role in assuring that the plan is implemented. This will require the FWS's commitment with respect to the consultation process and other areas. In addition, the scope and breadth of coordination clearly will require establishing a group to help facilitate recovery during the lengthy time frame contemplated in the plan.

Coordinating Group

The Recovery Team recommends a coordinating group be established to guide recovery activities over the long term. The coordinating group should be based regionally and explicitly constituted to facilitate interdisciplinary and managerial communication among action agencies, states, and the private sector in addressing the biological, forestry, and policy issues associated with recovery. This can be accomplished by including persons with technical expertise as members or, if members are management officials, by assuring the group's access to technical personnel. Each participant should determine an appropriate means of liaison with the group. For example, agencies could establish their own recovery implementation teams or regional advisory bodies.

Scope and functions. The coordinating group must be structured and its functions defined to avoid potential conflicts with the statutory mandates of the agencies involved. Therefore, the Recovery Team explicitly recommends no direct regulatory function for the group. This is to avoid creating the potential for confusion and duplication of effort of the FWS's section 7 consultation responsibilities under the Endangered Species Act, as well as the land management planning and operational mandates of action agencies. The Recovery Team recommends that the group be chartered to address the areas outlined in this section. These areas encompass broad policy and programmatic concerns that are critical to progress in the recovery effort and ultimately to achieve delisting.

- Recommend population and habitat monitoring standards and guidelines; provide technical advice to agencies in their implementation; and review results to assess progress.

- Provide a forum to coordinate research agendas of the various entities involved in recovery to assure that the plan's recommendations are addressed adequately and to maximize the value of the information produced.

- Facilitate data base consistency in the development and maintenance of technical information (particularly with respect to geographic information systems) and in monitoring and research activities, to maximize the validity and reliability of results, and to assure efficient use of funds and personnel.

- Review research results and make recommendations concerning management practices in areas such as silviculture to promote the adoption of desired actions in on-the-ground operations.

- Recommend recovery plan revisions based on the results of scientific research, monitoring, and the documented results of program operations.

- Promote dissemination of technical assistance to federal and state agencies, and to nonfederal parties, as appropriate, concerning issues related to recovery such as DCA management plan development and habitat manipulation.

- Assess policies, programs, plans, environmental impact statements, and regional guides with respect to their potential consistency with recovery objectives and provide recommendations for agency consideration.

- Promote effective communication and coordination among the various federal and nonfederal entities involved in recovery.

Organization and membership. The Recovery Team recommends the coordinating group's scope and functions be determined before organizational issues are addressed. The Recovery Team believes a variety of organizational options is available. Regardless of the arrangement chosen, however, the group's charter should be explicit to clearly establish its role. In addition, the Recovery Team believes membership should comprise federal and nonfederal entities, including the private sector. Accordingly, the group may require chartering under the Federal Advisory Committee Act.

6. Monitoring and Research

The primary objectives of the monitoring and research program are to determine whether implementation of the plan is on track, determine if implementation is producing expected effects, improve the plan over time, and, ultimately, determine when it is time to begin delisting procedures. Monitoring and research are intended to support the objective of this recovery plan, to provide stabilization and recovery of the northern spotted owl population with the lowest possible economic and social costs. The plan incorporates the considerable data available on northern spotted owls, one of the best researched owls in the world (see section II.A). These data give the Recovery Team reasonable assurance that the plan will succeed in its objective of recovering northern spotted owls. However, the Recovery Team is equally certain there is considerable room for refining and improving the plan and knowledge of owls. For example, the monitoring and research program may allow refinement of recommendations on types and amounts of dispersal habitat. Ongoing research programs which focus on ecological relationships and population dynamics of owls will provide considerable new information in the next several years. In addition, ongoing management will create a landscape different from the one in which owls have been observed to date, which will expand knowledge of owl ecology in a variety of habitat settings. For these reasons, the Recovery Team expects the monitoring and research program will provide information that can be used to improve the recovery plan over time. Improvements may allow increased security of the owl population and reduction of the economic cost of recovery. In addition, the monitoring and research program will provide information needed to determine when delisting of owl populations will be appropriate.

Significant monitoring and research efforts directed at northern spotted owls have been in place for many years. These are described in Thomas et al. (1990) and USDA (1988). The ideas and recommendations presented in this section of the recovery plan repeat some aspects of those ongoing programs and build on others. It was assumed that much of what is recommended can be implemented using existing organizational structures. However, some additional structure to provide overall coordination will be necessary for the recovery plan (see section III.C.5).

Functions of the Monitoring and Research Program

To be effective, the monitoring and research program must be designed carefully to answer specific questions about owls and their responses to landscapes created by management and natural events. The program can be organized into two basic categories: 1) information needed to consider delisting of the species; and 2) information needed for adaptive management under the recovery plan. While there is some overlap between these categories, they serve as a useful framework for discussing monitoring and research efforts.

Adaptive Management

The objective of the recovery plan is delisting of the northern spotted owl throughout its range. However, the decision to delist may be years or decades

away in some or all of the range. During that time, the monitoring and research program will have a vital function producing the information needed for changing and improving the implementation of the recovery plan. The process of using such information to refine management over time has been formalized as adaptive management (Holling 1978, Walters 1986). In this recovery plan, the objective of adaptive management is to improve the biological and economic efficiency of the plan while maintaining or increasing the level of protection for owls over time.

Successful use of adaptive management requires a carefully planned structure of monitoring, research, management reviews, and management refinement. The questions to be answered by monitoring and research must be designed specifically to provide information needed by management, and there should be checkpoints or trigger points that would initiate technical or administrative reviews, possibly resulting in management changes. As part of this structure, it is helpful to divide questions into three categories:

- Implementation questions — Was management direction implemented as specified?
- Effectiveness questions — Did the actions have the effects projected in the recovery plan?
- Validation/research questions — Are critical assumptions used in building the recovery plan correct?

All three categories of information must be collected for adaptive management to be effective. Implementation monitoring assures that implementing mechanisms are operating correctly and provides the basis for oversight. It is necessary to know that the plan was implemented correctly before effectiveness monitoring can be meaningful. Effectiveness monitoring provides the basis for determining if the primary effects predicted for the plan are occurring (e.g., is habitat becoming less fragmented within DCAs?). It provides the basis for deciding if some change is needed should the plan produce outcomes different from predictions. Validation monitoring and research provide information needed to determine if the key underlying assumptions of the plan are correct (e.g., that reproductive success of owls is related to the level of fragmentation of habitat). Validation monitoring is extremely important because it tells if a change in the recovery plan is necessary and what type of change might be appropriate. Without validation monitoring, it is possible to know that a change is needed but not know what type of change would be appropriate. Validation monitoring clearly represents a blend of scientific research and monitoring and is successful only when aimed at specific management questions.

The most important implementation, effectiveness, and validation monitoring questions follow.

Implementation monitoring questions.

1. Are DCAs being established on the ground following maps and guidelines from the recovery plan?
2. Are activities inside DCAs being implemented according to guidelines contained in the recovery plan? Have the land-managing agencies produced specific plans and guidance for activities in each of the DCAs?
3. Are matrix management guidelines being followed?

Effectiveness monitoring questions.

Habitat responses.

1. Do DCAs contain the target numbers of total acres and habitat acres?
2. Are activities inside DCAs producing the predicted forest structure over time?

3. Are activities in stands in the forest matrix producing the predicted forest structure over time?
4. Are desired landscape conditions being maintained over time in the matrix?
5. Are habitat trends and causes of those trends as predicted?

Owl population responses.

1. Do DCAs provide for predicted numbers of breeding owl pairs?
   a. Does each DCA provide for the predicted number?
   b. What proportion of DCAs falls above and below the predicted number?
2. Are owls moving successfully among DCAs?
3. Is the trend in numbers inside and outside the DCAs as predicted?
4. Are owls using created habitats inside and outside DCAs? What specific structural conditions are being used by owls and for what functions?

Validation monitoring/research questions.

Dispersal studies.

1. How well do various habitat conditions provide for dispersal of owls?
2. How well do various spacing distances among DCAs provide for dispersal of owls?
3. What is the type of use and relative degree of use of various habitat conditions by dispersing owls?

Spotted owl ecological relationships and population dynamics.

1. What is the range of forest structural conditions used by owls? How do owls use those conditions and what is the relative degree of use?
2. What are the specific stand features that influence the type and degree of owl use? These may include forest structure, species composition, amount and distribution of coarse woody debris, and number and distribution of snags.
3. How are owl reproductive success and survivorship related to habitat conditions, amount, distribution, and rate of change?
4. How are owl reproductive success and survivorship related to local population size?

Owl habitat relationships and management.

1. What is the influence of various management practices on forest stand composition and structure?
2. How do individual owls respond to management practices and resulting stand conditions within home ranges?
3. How do owl populations respond to management practices and resulting stand conditions within landscapes composed of multiple home ranges?
4. What are efficient and repeatable techniques for assessing habitat conditions at the stand and landscape scale?

Economics.

1. What are the costs and returns of various silvicultural practices that could be used to develop or sustain suitable habitat conditions?
2. How would various types of incentive systems operate to encourage landowner contribution to recovery?

Owl prey; prey relationships; and competitive relationships.

1. How do owl diets influence owl survivorship and reproductive success?
2. What are the patterns of abundance of principal prey species? How are they related to habitat conditions?
3. How do prey species respond to management practices and resulting stand conditions within owl home ranges?

4. What are the population dynamics patterns of principal prey species, and how are they influenced by habitat?
5. What are movement and dispersal patterns of prey species?
6. How do different habitat conditions affect competitive relationships between barred owls and spotted owls?

To facilitate the validation monitoring/research needed for adaptive management, the Recovery Team recommends that additional research areas be set-up near established demographic study areas within the federal matrix. The demographic study areas are described later. One research area per province would be desirable, and its area should be equivalent to its companion demographic study area. The Recovery Team recommends that these research areas have as their goal replicated experiments to evaluate 1) the response of owls to timber harvest, 2) the utility of various silvicultural prescriptions in producing habitat for owls, 3) emigration and immigration rates in response to a changing landscape, and 4) the demographic response of the owl population within the area. Experiments in these research areas can occur in currently suitable habitat, and will contribute to the objective of the recovery plan to delist the owl across its range and to achieve forest silviculture that is compatible with owls across the landscape. Inferences regarding the compatibility of timber harvest with owls can be achieved only through the execution of controlled, replicated experiments. It is essential that the principle investigators of the companion demography and experimental research areas agree to full cooperation before establishing the research protocol on the experimental areas.

The Recovery Team also recommends that research continue on the Yakima Indian Nation land and on private land throughout the range of the owl. Ongoing research on Yakima land is a unique study of owl population responses to a forested landscape that has been managed through an uneven-aged silvicultural regime.

Adaptive Management Procedures

To realize the objectives of the monitoring and research program, there must be a process in place that will guide how the results of the program will be used. This process must include agreement on specific monitoring and research results that will trigger review and possible revision of the recovery plan. Such reviews could take place as part of a review cycle for the recovery plan or at any other time. The Recovery Team strongly recommends that such trigger points be developed for at least the following potential actions:

1. Determine when it would be appropriate to modify DCA boundaries based on owl numbers or suitable habitat availability that fall below or above projections.

If numbers of owls or amounts of suitable habitat are found to be above predicted levels in one or more DCAs, it may be appropriate to either reduce the size of those DCAs or to allow greater flexibility of management within them (see the next potential action). However, it first should be determined that the high populations are not the result of "packing" phenomena (Thomas et al. 1990) and that the proposed management has been demonstrated to produce desired habitat conditions for owls. Review of any individual DCA should be done within the context of an entire province to ensure that a key source area is not weakened. If one or more DCAs are below objective levels, it may be necessary to modify DCA boundaries and possibly increase their size or the quality of habitat within the DCA boundary. In this case, it first should be determined that the low numbers of owls are not related to short-term demographic responses. Finally, it may be appropriate to eliminate DCA boundaries

when the population of owls in the matrix is at the level of those found in the DCA, their demographic rates are similar to those in DCAs, and forest management has been demonstrated to be compatible with the owls.

2. Determine when it would be appropriate to broaden management recommendations within DCAs based on 1) achievement of stable, self-sustaining numbers of owls or amounts of suitable habitat that exceed predictions, 2) demonstrated success of management activities in providing for owls, or 3) demonstrated need to reduce likelihood of large-scale disturbances.

The recovery plan recommends that some forms of salvage be allowed within DCAs and that some limited attempts begin to use management to improve habitat and to decrease the risk of disturbance. Monitoring both the implementation and effectiveness of these activities is crucial because they will influence the capability of the DCAs to support owls. As monitoring adds to knowledge about the use of management practices in DCAs, it may be useful to increase and broaden application of those practices. If management is demonstrated to be useful in developing younger, currently unsuitable stands, the use of such management should be encouraged beyond the levels established in this plan. If management is shown to be useful in older stands, recommendations may be broadened to include those stands. If owl numbers or amounts of suitable habitat exceed predictions, it may be useful to define a core area of the DCA that would continue to be managed under current guidelines and additional areas that would be managed with fewer restrictions on the use of silviculture, salvage, and other management options. Finally, if the ability to maintain suitable habitat while reducing the risk of large-scale disturbance is demonstrated, such activities should be encouraged within DCAs that are at high risk.

3. Determine when it would be appropriate to end special management for reserved pair areas based on improved conditions in individual DCAs or groups of DCAs.

The recovery plan recommends that additional pair areas be established where the DCA system is currently deficient. If those deficiencies are corrected, it may be appropriate to modify management within those pair areas.

4. Determine when it would be appropriate to supplement or modify the DCA system based on unexpectedly poor performance of owl populations (i.e., survival rates, fecundity rates, and immigration rates).

The monitoring and research program will provide data on the population dynamics of owls within the DCA system. If it becomes clear that populations are not replacing themselves within these areas, or that immigration is not occurring as expected among areas, one of the following actions may be appropriate:

a. Modify DCAs where possible to include any contiguous areas of high owl concentrations and habitat with low levels of fragmentation.
b. Add new DCAs to the system, emphasizing areas of high owl concentration and high quality habitat.
c. Add new DCAs to the system with the primary objective of reducing the dispersal distance among DCAs.
d. Modify the recommendations for management within DCAs.

5. Determine when it would be appropriate to modify matrix management recommendations based on impending isolation of DCA subpopulations determined through unexpectedly low rates of movement among DCAs.

If the monitoring and research program shows unexpectedly low rates of movement among DCAs, or provides new knowledge of limited dispersal of owls in various forest types, it may be necessary to either supplement the DCA system (see earlier recommendation) or change the management of the matrix.

6. Determine when it would be appropriate to modify matrix management recommendations based on information that owls disperse successfully through habitats of smaller trees and lower canopy closure.

If the monitoring and research program shows high rates of successful dispersal through forests with small trees and/or low quality habitat, it may be appropriate to relax recommendations for dispersal habitat.

Primary Information Needed for Delisting Northern Spotted Owl Populations

The criteria for delisting are explained in section III.A. They are 1) that owl populations and habitat be monitored with a scientifically credible plan, 2) that the population be stable or increasing, 3) that commitments be in place to provide long-term protection of habitat, and 4) that information from a variety of sources indicates that the population will not need renewed protection under the Endangered Species Act. The following section describes the hypotheses that must be tested to satisfy delisting criteria 2 and 4 and the specific information that must be collected to test those hypotheses.

Delisting Criterion 2: *The population has been stable or increasing during at least the last 8 years, as indicated by both density estimates and demographic analyses, in all parts of the area that would be considered significant under the Endangered Species Act.*

Hypothesis 1
The change in total number of territorial owls over time is greater than or equal to zero.

Information needed to test hypothesis 1
An estimate or index of the number of territorial owls repeated over time is needed. At a minimum, there must be an adequate estimate made for each physiographic province. Estimates over smaller geographic areas should be made if those areas would be considered significant under the Endangered Species Act. Within the provinces, the estimate should be stratified into DCAs and forestlands outside DCAs. These separate estimates then must be combined into a single estimate for the entire province.

Hypothesis 2
The finite rate of increase of owl populations is greater than or equal to zero as determined from estimates over time of demographic parameters.

Information needed to test hypothesis 2
Estimates over time of age-specific or stage-specific survival and reproduction rates, including age at first and last reproduction, are required. Estimates should be made for at least one subpopulation within each physiographic province, with the subpopulation sufficiently large to produce statistically reliable estimates of the demographic parameters. Estimates for additional subpopulations may be necessary to fully represent the range of ecological conditions within each province.

Delisting Criterion 4: *The population is unlikely to need protection under the Endangered Species Act during the foreseeable future.*

Hypothesis 1
Long-term demographic projections, that include the effects of fluctuations in abundance, fecundity, and survivorship, indicate that there is a high probability of persistence of the population for 100 years.

Information needed to test hypothesis 1
The data collected to answer questions about population and demographic trends over time can be used in a modeling context to respond to this hypothesis. It is important to emphasize that, within the context of metapopulation dynamics, some DCA subpopulations may decline for a variety of reasons (e.g., catastrophic events, random demographic events) even when the metapopulation is stable. Therefore, delisting could occur in the province if the metapopulation as a whole were stable even though some DCAs would not be contributing fully for short periods.

Hypothesis 2
There are sufficient immigrants per generation among DCAs to maintain demographic stability and genetic diversity.

Information needed to test hypothesis 2
Data are necessary for the number of immigrants per generation into DCAs. These data can be collected best in conjunction with the studies of demographic rates.

Hypothesis 3
Changes in amount and distribution of northern spotted owl habitat occur at expected rates and result from expected causes.

Information needed to test hypothesis 3
Estimates over time of amounts and distribution of various classes of habitat are needed. These estimates must account for the development of suitable conditions on some areas and the loss of suitable conditions on others.

The Recovery Team makes the following recommendations for study areas and techniques for collection of information needed for delisting.

Demography. Demographic study areas will provide information on demographic (i.e., vital) rates (e.g., age-specific, stage-specific rates of fecundity and survival, age at first and last reproduction) and the occurrence of immigration. These are large areas, tens to hundreds of square miles, where as many owls as possible are banded. Banding is done on adult, subadult, and juvenile owls. Owls are observed on an annual basis on territorial sites, and young are observed annually on nest sites. These observations are used to determine age-specific or stage-specific fecundity and mortality rates. Procedures for developing some of these estimates are explained further in Appendices A and C. There are currently seven demographic study areas which should form the basis for assessments of demographic trends within their respective provinces. These study areas are located in the following provinces: Olympic Peninsula; eastern Washington Cascades; western Oregon Cascades; Oregon Coast; and California Coast. An additional demographic area should be established in the western Washington Cascades. Three provinces — western Washington

lowlands, eastern Oregon Cascades, eastern California Cascades — currently cannot support demographic studies equivalent to those found in the other provinces because of low owl numbers. Density and demographic studies could be initiated in these provinces when their owl populations have increased to the point that delisting can be considered.

General recommendations for demographic studies are as follows:

1. Maintain existing demographic study areas. Since owls are long-lived animals, long duration population studies will be necessary to estimate population trends. Assessment of annual changes in vital rates is necessary to draw appropriate inferences from the study. The most cost-effective way to evaluate owl populations is to continue the demographic studies. The longer a study has existed the more valuable it is for assessing trends in demography.

2. Expand demographic study areas to include larger areas that will encompass owls within several DCAs and the province matrix. This will allow some estimation of immigration into DCAs. While this will not allow an absolute estimate of the number of immigrants, it will provide evidence that immigration is occurring and it will provide estimates of the sources of the immigrants and distances traveled. Such large study areas encompassing the demography study areas also would improve the analysis of regional trends in demography.

3. Monitor demographic trends in both the matrix and the DCA network within each province. Franklin and Gutiérrez (unpub. data) indicate that individual owl pairs monitored throughout the California Klamath province have the same (i.e., not statistically different) vital rates as a population of contiguous owls in the Willow Creek demographic study area. The cost for this monitoring is minimal and could be conducted in conjunction with the current demographic studies (Appendix A).

Owl population trends. Numerical trends of owls should be monitored in the matrix and DCA network within each province. Several methods have been developed to estimate numerical and density estimates for owls including transect sampling (Forsman et al. 1977), capture-recapture models, empirical estimation, quadrat sampling (Franklin et al. 1990b), and catch per unit effort models (Ward et al. 1991). Additional sampling procedures are presented in Appendix A.

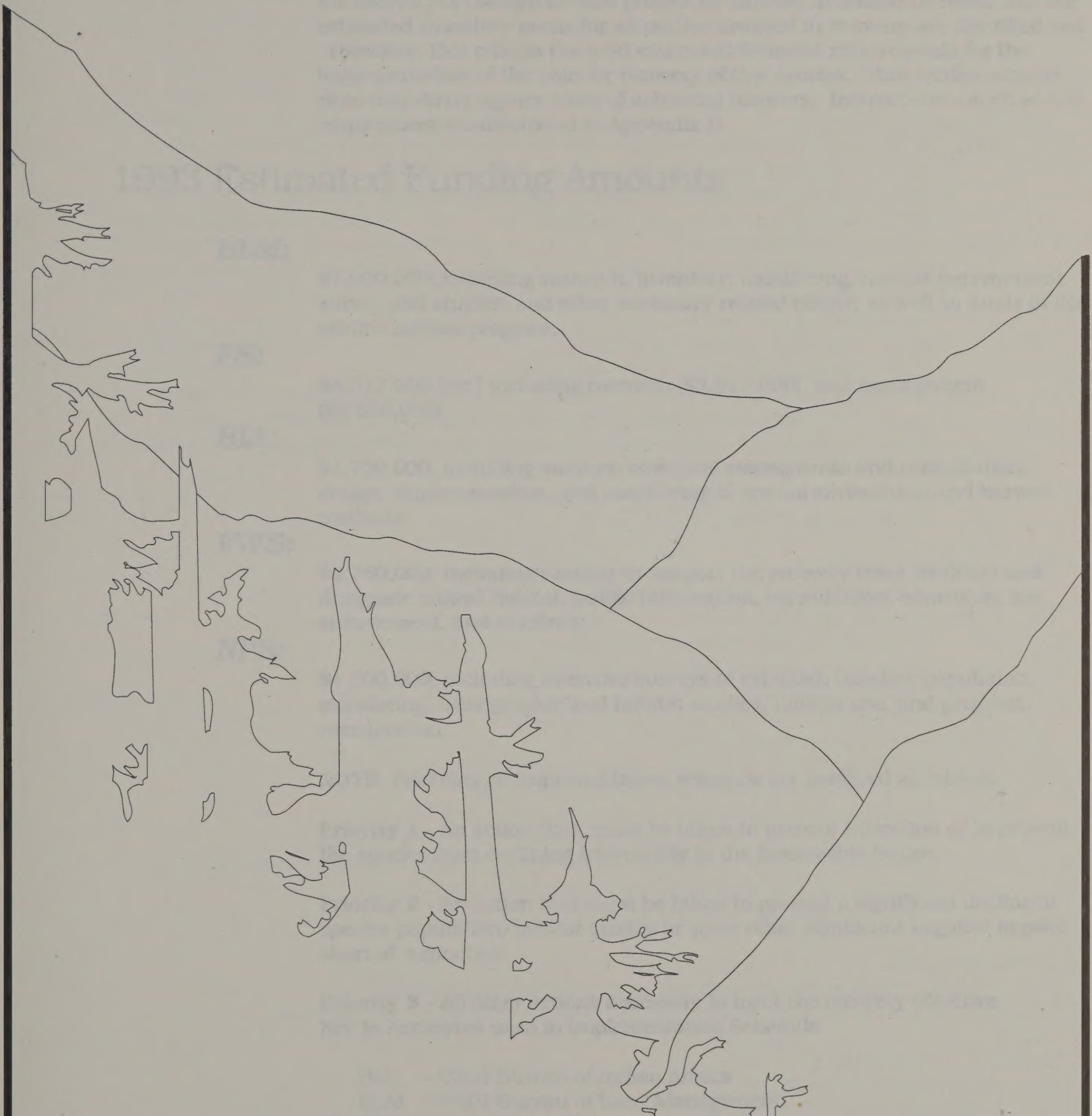
Population Modeling. Mathematical modeling is a powerful tool for assessing population dynamics. The Recovery Team recommends that the development of models, such as those produced by scientists at the Forest Service Redwood Sciences Laboratory, continue.

Coordination

The monitoring and research effort must be coordinated among the responsible federal agencies and state agencies, and private interests, including universities. This coordination should be part of the function of the coordinating group established during the implementation of this plan (see section III.C.5). The coordinating group will help ensure that all required parts of the monitoring program are conducted; that monitoring designs are coordinated among agencies and landowners; that the monitoring proceeds according to design; that monitoring reports are prepared and reviewed on an established schedule; that periodic reviews are made to see if management adjustments are needed or desirable; and that recommended research activities are coordinated among agencies so that research is efficient and representative of the entire range of the subspecies.

Chapter IV

Implementation Schedule



IV.

The narrative and implementation schedule that follow outline actions and estimated costs for the recovery program. This chapter is a guide for meeting the objective discussed in the plan. The schedule indicates task priorities, task numbers, task descriptions, duration of tasks, the responsible agencies, and lastly, estimated costs. These actions, when accomplished, should bring about the recovery of the species and protect its habitat. It should be noted that the estimated monetary needs for all parties involved in recovery are identified and , therefore, this reflects the total estimated financial requirements for the implementation of the plan for recovery of this species. This section summarizes only direct agency costs of achieving recovery. Indirect costs such as lost employment are discussed in Appendix H.

1993 Estimated Funding Amounts

BLM:

$7,000,000; including research, inventory, monitoring, habitat improvement survey and studies, and other necessary related efforts, as well as funds in the wildlife habitat program.

FS:

$8,917,000 (est.) including research ($2,917,000), and management ($6,000,000).

BIA:

$1,700,000, including surveys, biological assessments and consultation, design, implementation, and monitoring of special silvicultural and harvest methods.

FWS:

$2,760,000, including funding to support the recovery team, evaluate and designate critical habitat, public information, consultation, education, law enforcement, and research.

NPS:

$1,500,000, including intensive surveys to establish baseline population, monitoring, demographic and habitat studies, habitat use, and program coordination.

NOTE Priorities on implementation schedule are assigned as follows:

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to meet the recovery objective.
Key to Acronyms used in Implementation Schedule

BIA	- USDI Bureau of Indian Affairs
BLM	- USDI Bureau of Land Management
FS	- USDA Forest Service
FWS	- USDI Fish and Wildlife Service
NPS	- USDI National Park Service
RT	- Recovery Team (or the coordinating group recommended in the plan)
SA	- State Agency
UNIV	- University (Humboldt State, Oregon State, Washington State, etc.)

Stepdown Outline

1. Management Tasks.
   11. Review recovery plan.
   12. Establish coordination group.
   13. Implement recommendations regarding DCAs.
       131. Establish DCAs.
       132. Prepare guidelines for activities in DCAs.
       133. Prepare DCA management plans.
            1331. Prepare demonstration plans.
            1332. Prepare remainder of plans.
            1333. Implement DCA plans.
   14. Manage the federal matrix.
       141. Implement Prescription A.
            1411. Establish residual habitat areas.
            1412. Implement residual area management guidelines.
            1413. Implement "50-11-40" guideline.
       142. Implement Prescription B.
            1421. Establish reserve pair areas.
            1422. Implement reserve pair management guidelines.
       143. Implement Prescription C.
            1431. Establish managed pair areas.
            1432. Implement managed pair guidelines.
       144. Implement Prescription D as appropriate.
            1441. Evaluate potential contribution of Prescription D to recovery.
            1442. Implement Prescription D where it will contribute to recovery.
   15. Manage non-Federal lands.
       151. Establish measurable goals.
       152. Develop plans to meet goals.

2. Regulatory mechanisms.
   21. Propose formal adoption of the recovery plan.
   22. Revise existing regulatory measures as appropriate.
       221. Revise critical habitat boundaries to follow DCA boundaries.
       222. Revise or amend land management plans.
   23. Enforce taking prohibition.
   24. Publish regulations interpreting taking prohibitions.
   25. Advise owners and managers of land.
       251. Provide guidance on programmatic consultation.
       252. Conduct consultations regarding federal actions.
       253. Provide technical assistance to non-federal landowners.
            2531. Assist States in developing protective management plans.
            2532. Assist private landowners in developing Habitat Conservation Plans.
            2533. Assist with spotted owl studies and surveys.
            2534. Evaluate potential usefulness of special rules.

3. Land Acquisition.
   31. Evaluate opportunities for land exchange, easement, or purchase.
   32. Acquire land or interest in land through exchange, easement, or purchase.

4. Research and Monitoring.
   41. Maintain and refine GIS.
   42. Implement monitoring program.
       421. Agree on objectives and methods.
       422. Conduct roadside surveys.
            4221. Design surveys.
            4222. Carry out surveys.

- 423. Monitor activity sites.
  - 4231. Estimate sample size.
  - 4232. Carry out monitoring.
- 424. Study demographic analyses.
- 425. Study population models.
- 426. Develop early warning methods.

43. Study habitat suitability.
- 431. Standardize habitat measurements.
- 432. Prepare habitat maps for demographic study areas.
- 433. Study suitability in selected areas.
  - 4331. Study California coast.
  - 4332. Study eastern California.
  - 4333. Study eastern Cascades.
- 434. Evaluate suitability of selected habitats.
  - 4341. Evaluate young plantations with remnant larger trees.
  - 4342. Evaluate stands managed with selective harvest.
  - 4343. Evaluate areas in which salvage is economically feasible.

44. Conduct demographic studies.
- 441. Continue well-established studies.
- 442. Consider need for additional studies.
- 443. Initiate new studies as appropriate.

5. Review and Evaluation.

51. Prepare reports.
- 511. Prepare annual progress reports.
- 512. Prepare 5-year evaluation report.

52. Review recovery plan and revise as appropriate.

Table 4.1 Abbreviated Cost Table

The following table identifies estimated costs by broad category from the stepdown outline for the federal agencies. More detailed cost estimates will be incorporated into the implementation schedule before approval of the final recovery plan.

		Estimated Cost (x1000)		
Cost Category	**Agency**	**FY93**	**FY94**	**FY95**
1. Management Tasks	BLM	4,100	10,800	12,000
	BIA	425	25	25
	FWS	800	1,000	1,000
	FS	2,230	3,800	4,200
	NPS	70	100	100
2. Regulatory Mechanisms	BLM	590	1,500	750[1]
	BIA	325	325	300[1]
	FWS	1,260	1,500	1,200[1]
	FS	1,690	2,800	500[1]
3. Land Acquisition[2]				
4. Research and Monitoring	BLM	2,100	5,250	5,250
	BIA	900	900	900
	FWS	600	600	600
	FS	4,727	7,900	8,200
	NPS	1,400	1,500	1,600
5. Review and Evaluation	BLM	210	500	500
	BIA	50	50	50
	FWS	100	100	100
	FS	270	500	800
	NPS	30	50	50
Totals	BLM	7,000	18,050	18,500
	BIA	1,700	1,700	1,675
	FWS	2,760	3,200	2,900
	FS	8,917	15,000	13,700
	NPS	1,500	1,650	1,750

[1] Reduced regulatory expenditures in FY 95 are based on the expectation that programmatic consultation will be instituted.

[2] Costs in the this category cannot be estimated pending completion of agency management plans.

Table 4.2. Implementation Schedule

Task Priority	Task	Task No.	Duration (years)	Resp. Party FWS Reg.	Resp. Party FWS Prog.	Resp. Party Other	Cost Est. (x$1000) 1993	-94	-95
1	Establish DCAs	131	2			FS BLM NPS			
1	Establish residual	1411	1			FS BLM			
1	Implement 50-11-40	1413	cont.			FS BLM			
1	Establish reserve pair areas	1421	1			FS BLM			
1	Implement reserve pair management guidelines	1422	1			FS BLM			
1	Establish managed pair areas	1431	1			FS BLM			
1	Implement managed pair guidelines	1432	1			FS BLM			
1	Propose formal adoption of plan	21	1	1	FWE	FS BLM NPS			
1	Enforce taking prohibition	23	cont.	1	LE				
2	Establish coordination group	12	1	1	FWE	FS BLM NPS CA OR WA			
2	Implement residual area guidelines	1412	cont.			FS BLM			
2	Establish non-federal goals	151	1			CA OR			
2	Develop nonfederal plans	152	2			CA OR WA			
2	Revise or amend federal plans	222	1			FS BLM			
2	Review and revise plan	52	1						
3	Review plan	11	1	1	FWE				
3	Prepare DCA guidelines	132	1			FS BLM NPS			
3	Prepare demo plans	1331	1			FS BLM NPS			
3	Prepare remaining plans	1332	2			FS BLM NPS			

continues—

continued—

Task Priority	Task	Task No.	Duration (years)	Resp. Party Reg.	Resp. Party FWS Prog.	Resp. Party Other	Cost Est. (x$1000) 1993	-94	-95
3	Implement DCA plans	1333	cont.			FS BLM NPS			
3	Evaluate prescription D	1441	1	1	FWE	 FS BLM NPS			
3	Implement prescription D as appropriate	1442	cont.			FS BLM			
3	Revise critical habitat boundaries	221	1		FWE				
3	Publish take	24	1	1	FWE				
3	Provide guidance on programmatic consultation	251	1	1	FWE				
3	Conduct consultation	252	cont.	1	FWE	FS BLM NPS			
3	Assist states in planning	2531	cont.	1	FWE				
3	Assist private planning	2532	cont.	1	FWE				
3	Assist with studies and surveys	2533	cont.	1	FWE				
3	Evaluate special rules	2534	1	1	FWE				
3	Evaluate acquisition opportunities	31				FS BLM NPS CA OR WA			
3	Acquire land as	32				FS BLM NPS CA OR WA			
3	Maintain GIS	41	cont.			RT	50	50	50
3	Agree on objectives and methods for monitoring	421	1	1	FWE	 RT FS BLM NPS CA OR WA			
3	Design roadside surveys	4221	2			RT			
3	Carry out roadside surveys	4222	cont.			FS BLM NPS CA			

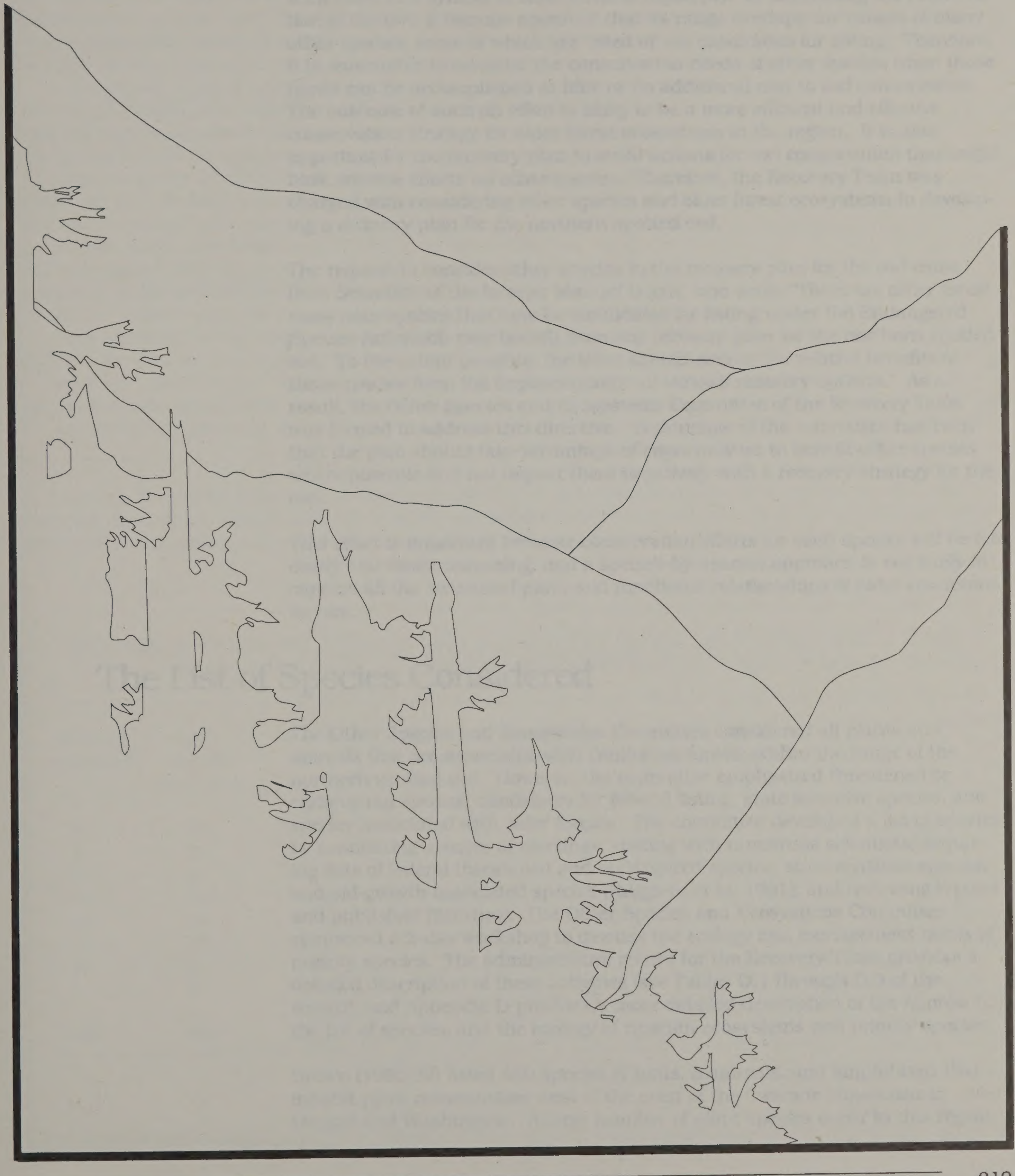
continues—

continued—

Task Priority	Task	Task No.	Duration (years)	Resp. Party FWS Reg.	Resp. Party FWS Prog.	Other	Cost Est. (x$1000) 1993	-94	-95
						OR WA			
3	Estimate sample	4231	1			RT	2	1	
3	Carry out monitoring	4232	cont.			RT FS BLM NPS CA OR WA			
3	Study demographic analyses	424	3			RT FS BLM			
3	Study population models	425	3	1	FWE	RT FS BLM NPS			
3	Develop early warning methods	426	cont.			RT			
3	Standardize habitat measurements	431	1			RT			
3	Prepare habitat maps	432	2			RT FS			
		BLM							
3	Study habitat suitability in selected areas	433	3			RT FS BLM			
3	Study suitability of selected habitats	434	3			RT FS BLM			
3	Continue willow creek study	4411							
3	Continue Roseburg	4412							
3	Consider new demography studies	442	1			RT FS			
		BLM							
3	Initiate new demography studies	443	cont.			RT FS BLM			
3	Prepare annual reports	511	cont.			FS BLM NPS BIA CA OR WA			
3	Prepare 5-year report	512	1			FS BLM NPS BIA CA OR WA			

Chapter V

Consideration of Other Species



V.

The northern spotted owl is associated with older coniferous forests in the Pacific Northwest (Forsman et al. 1984, Thomas et al. 1990), and optimal habitat for the species can be found in forests older than 200 years. Because of this association and the large home ranges of spotted owls, which vary from 1,000 to 10,000 acres from California to Washington, the species often has been used as a symbol of older forest ecosystems. In addressing the conservation of the owl, it became apparent that its range overlaps the ranges of many other species, some of which are listed or are candidates for listing. Therefore, it is reasonable to consider the conservation needs of other species when those needs can be accomplished at little or no additional cost to owl conservation. The outcome of such an effort is likely to be a more efficient and effective conservation strategy for older forest ecosystems in the region. It is also important for the recovery plan to avoid actions for owl conservation that might have adverse effects on other species. Therefore, the Recovery Team was charged with considering other species and older forest ecosystems in developing a recovery plan for the northern spotted owl.

The request to consider other species in the recovery plan for the owl came from Secretary of the Interior Manuel Lujan, who wrote "There are other forest ecosystem species that may be candidates for listing under the Endangered Species Act which may benefit from any recovery plan for the northern spotted owl. To the extent possible, the team should assess the relative benefits to these species from the implementation of various recovery options." As a result, the Other Species and Ecosystems Committee of the Recovery Team was formed to address this directive. A principle of the committee has been that the plan should take advantage of opportunities to benefit other species where possible and not impact them negatively with a recovery strategy for the owl.

This effort is important because conservation efforts for each species will be too costly and time consuming, and a species-by-species approach is not likely to capture all the structural parts and functional relationships of older coniferous forests.

The List of Species Considered

The Other Species and Ecosystems Committee considered all plants and animals that are associated with coniferous forests within the range of the northern spotted owl. However, the committee emphasized threatened or endangered species, candidates for federal listing, state sensitive species, and species associated with older forests. The committee developed a list of species by conducting a series of meetings; visiting with numerous scientists; acquiring lists of federal threatened and endangered species, state sensitive species, and old-growth associated species (Ruggiero et al. 1991); and reviewing reports and published literature. The Other Species and Ecosystems Committee sponsored a 2-day workshop to discuss the ecology and management needs of priority species. The administrative record for the Recovery Team provides a detailed description of these activities (see Tables D.1 through D.3 of the record); and Appendix D provides a more detailed description of the approach, the list of species, and the ecology of riparian ecosystems and priority species.

Brown (1985:37) listed 460 species of birds, mammals, and amphibians that inhabit plant communities west of the crest of the Cascade Mountains in Oregon and Washington. A large number of plant species occur in this region,

and the number of invertebrate animals is believed to be large, but cannot be estimated accurately because many of the arthropods (Lattin pers. comm.) and molluscs (Frest and Johannes 1991) have not been surveyed or described adequately. The biota of coniferous forests in the Pacific Northwest is extremely rich in numbers of species and possesses numerous species that occur only in the region (endemic) and are unique among their taxonomic relatives (see Appendix D).

Species considered for incorporation into the recovery plan for the owl include 361 species of plants and animals (Table 5.1). Of those, five are listed federally as threatened or endangered, 155 are candidates for listing, and approximately 100 are species of special concern in one or more of the three states. Approximately 100 of the species are narrowly or broadly endemic to the Pacific Northwest, and 194 are associated with older forests. In addition, the 28 fish species include approximately 766 stocks that are considered at risk (Nehlsen et al. 1991), and many of these may become candidates for federal listing in the future. The large number of candidates for federal listing, species of special concern, endemic species, and older forest associates (Table 5.1) in the Pacific Northwest emphasizes the importance of considering other species in the owl recovery plan. The large number of species associated with rivers, creeks, ponds, and marshes and their associated vegetation (riparian areas) plus the number of fish stocks at risk, are indicative of the importance of considering riparian ecosystems. Most riparian ecosystems west of the crest of the Cascade Mountains in Oregon, Washington, and in northwest California are associated with coniferous forests, used by northern spotted owls for nesting or foraging (see Appendix D), and influenced by land use practices. The individual species considered by the committee, plus their status and association with riparian areas and older forests, are listed in Appendix D, Tables D.1 through D.8.

From the large list of species, the committee identified 18 priority species (marbled murrelet, bald eagle, goshawk, marten, fisher, grizzly bear, gray wolf, Oregon slender salamander, Siskiyou Mountain salamander, Larch Mountain

Table 5.1. Summary of 361 plants and animals considered in the recovery planning process for the northern spotted owl (from Appendix D: Tables D.1—D.8).

	Federally Listed	Candidate for Listing	State Listed	Species of Special Concern	Endemic[a]	Older Forest Associate	Riparian Associate
Birds (23)	1	2	4	8	4	20	3
Mammals (18)	2	2	3	9	8	12	4
Amphibians[b] (23)	0	7	3	16	20	12	12
Fish (28)	1	7	3	25	N/A	N/A	28
Molluscs (58)	0	10	1	29	47	43	45
Insects (59)	0	34	0	?	?	23	34
Vascular Plants (146)	1	93	16	42	23	76	6
Fungi and Lichens (8)	0	0	?	2	?	8	0
Total (N=361)	**5**	**155**	**30**	**131**	**102**	**194**	**132**

[a]Locally or broadly endemic.
[b]Includes two reptiles, the sharptail snake and western pond turtle.
N/A = not applicable
? = unknown, undetermined

salamander, Del Norte salamander, Pacific giant salamander, Cope's giant salamander, Olympic salamander (four species), tailed frog); a larger list of riparian-associated species including fishes, amphibians, mammals, insects, and molluscs; and a list of five species preyed upon by the owl (flying squirrel, bushy-tailed woodrat, dusky-footed woodrat, red tree vole, and western red-backed vole). Of these species, the marbled murrelet and the numerous fish stocks were assigned the highest priority because of the proposal to list the marbled murrelet as a threatened species and because the numerous fish stocks are considered at risk. The threatened or endangered species were not assigned as much importance because the committee assumed that their management is sufficiently addressed in recovery plans for each of the species.

Benefits of the Plan to Other Species

This section describes the benefits that other species will derive from the recovery plan for the northern spotted owl. Many of these benefits cannot be quantified adequately until surveys of the DCAs for other species have been conducted. However, some reasonably accurate statements can made.

Designated Conservation Areas (DCAs)

The size, spacing, and management of DCAs will provide considerable benefits for other species throughout the owl's range, particularly species associated with older forests. As a result of DCA placement, benefits to other species will be attained with little or no additional cost. For example, two category 2 DCAs were established in the Mt. Baker-Snoqualmie National Forest to include seven pairs of owls and a wild and scenic river corridor along the South Fork of the Stillaguamish River. These DCAs also include marbled murrelet locations and important stream sections for native fishes. The additional area was offset by reductions in the size of the habitat conservation areas (HCAs) recommended by the ISC report (Thomas et al. 1990). In Oregon, a DCA was established in the Suislaw National Forest (Lincoln County) along the coastal area near Rock, Cummins, and Tenmile Creeks. This DCA includes eight owl pairs and eight single owls as well as 60 sites for marbled murrelets and three streams with fish stocks at risk. This addition also was offset by reductions in the size of two of the HCAs that were recommended by the ISC report.

The benefit of DCAs to priority species can be quantified by totaling the number of occurrences (occupied nest sites for birds, trap locations or observations for mammals) of these species within DCAs for each province (Table 5.2). The DCA network incorporates a total of 486 known sites of priority species across the range of the owl, including 227 occupied murrelet sites, 122 goshawk nest sites, 60 marten sites, 37 fisher sites, and 40 bald eagle nest sites. The DCAs also include 2,047 miles of streams with stocks of fish that are considered at risk. The greatest benefits to fish will be achieved in the Klamath physiographic province and the Oregon Coast Range where 696 and 267 miles of streams, respectively, were included in DCAs. The greatest benefits to other species will be achieved for marbled murrelets in the Oregon Coast Range where 146 occupied sites are included in DCAs. Forty-seven goshawk sites in the western Washington Cascades and 32 murrelet sites on the Olympic Peninsula were included in DCAs. These are known sites and probably do not represent all sites for these species in DCAs. Inclusion of these sites in DCAs, along with the conservation of older forests for owl habitat, will provide significant benefits to these species within the range of the spotted owl.

Management guidelines for DCAs on federal lands are key elements of the recovery plan (see section III.C.2.). These guidelines focus on the maintenance of suitable habitat for owls and development of suitable habitat in stands

Table 5.2. Numbers of other species locations and miles of streams (with fish stocks at risk) in designated conservation areas (DCAs) for the northern spotted owl summarized by physiographic province.

Province	Bald[a] Eagle	Fisher[b]	Goshawk[a]	Marten[b]	Murrelet[c]	Miles of Stream
	Species					
California Cascades	3	0	8	5	N/A	80
California Coast Range	0	0	0	0	17	184
Klamath (Oregon and California)	2	18	20	14	11	696
Eastern Oregon Cascades	3	1	8	7	N/A	32
Western Oregon Cascades	4	2	11	8	N/A	232
Oregon Coast Range	8	1	0	0	146	267
Olympic Peninsula	9	6	12	0	32	202
Eastern Washington Cascades	1	2	16	7	N/A	136
Western Washington Cascades	7	7	47	19	19	203
Western Washington Lowlands	3	0	0	0	2	13
Total in DCAs	**40**	**37**	**122**	**60**	**227**	**2,047**
Total in Range	**1,070**	**107**	**256**	**219**	**367**	**-**

[a]Locations are nest sites.
[b]Locations are sightings or trap records.
[c]Locations are nest sites and areas that have been repeatedly used by murrelets.
N/A = not applicable; murrelets occur less than 50 miles from the Pacific Ocean.
- (dash) = data not available.

currently unsuitable. The guidelines specify the kinds of silvicultural activities and salvage that may occur within DCAs, and they suggest ways of managing to limit large-scale disturbance (fire, wind) of habitat in some of the provinces. All of these guidelines are designed to protect and enhance owl habitat. As a result of adhering to the management guidelines, forest areas within the DCAs will provide habitat for a wide array of other species.

Management guidelines for salvage within DCAs are designed to retain course woody debris (snags and down logs) after large-scale disturbances. This management will contribute to the habitat requirements of a number of cavity dwellers including cavity-nesting birds and flying squirrels through retention of coarse woody debris. These guidelines also will promote suitable conditions for arthropods, salamanders, fungi, and small mammals that use these habitat features.

Management in the Forest Matrix

Recommendations for management of the forestlands outside of DCAs (forest matrix) on federal lands are designed to provide habitat for dispersing juvenile owls and for pairs and territorial singles, where the DCA network is deficient or there is a risk of large-scale disturbance (see section III.C.2.). Management of the matrix for dispersing owls only is not likely to provide the necessary habitat for many species associated with older forests. However, the matrix on federal land outside of DCAs also will be managed to protect residual habitat areas, reserved pair areas, and managed pair areas, which will provide habitat for other species associated with older forests. Habitat around managed pair areas may be maintained through time using various management techniques, and there is some uncertainty about what benefits it will provide to other species. However, if some of these management techniques include longer rotations and uneven-aged management with a goal of providing large trees, snags, and coarse woody debris, these areas will be used by a number of species. The Yakima Indian Reservation and private lands in northern California present opportunities to evaluate this type of management in mixed-conifer forests. Unfortunately, this type of management has been conducted in few areas in the Douglas-fir/hemlock forests of western Oregon and Washington.

Further Surveys, Inventory, and Research

The committee also identified species within the range of the northern spotted owl for which little is known or further review would be appropriate. The committee developed four criteria for evaluating each species' current status including:

1. Possession of an extremely restricted geographic range.
2. A federal classification as a category 2 or 3 species for listing.
3. Designation as a species of special concern or sensitive species in one or more states.
4. Lack of information on distribution and or population numbers.

The committee also emphasized species that are endemic to the Pacific Northwest and associated with older forests. The species suggested for further review include:

Birds: goshawk, Vaux's swift, white-headed woodpecker, black-backed woodpecker, pigmy owl.
Mammals: fisher, marten, red tree vole (two species), white-footed vole, forest deer mouse, long-legged myotis, fringed myotis.

Amphibians and Reptiles: Larch Mountain salamander, Van Dyke's salamander, Oregon slender salamander, Siskiyou Mountain salamander, Del Norte salamander, Dunn's salamander, Olympic salamander (four species), Pacific giant salamander, Cope's giant salamander, tailed frog, sharptail snake, western pond turtle.
Fishes: bull trout, coastal sea run cutthroat, tidewater goby.

The Recovery Team suggests additional surveys, inventory, and research for these species, based on what is known about their current status (see Appendix D tables).

Arthropods and molluscs are two major groups of organisms in the region for which there is little information and a great need for status reviews, surveys, and research. Neither group has been surveyed adequately throughout the range of the northern spotted owl, and many species are not described or named. Any assessment of their status will require considerable effort and should be approached through broad-scale inventories aimed at assessing species composition and distribution. In addition, surveys of the amphibians in the Pacific Northwest currently are inadequate to assess the status of many of their populations. This is particularly important, because many of the amphibians have restricted distributions, limited dispersal capabilities, and high genetic variability, which are characteristics of species that become rare and eventually are listed as threatened or endangered. Much of the existing information on the abundance of amphibians in different ages of coniferous forests is presented by Ruggiero et al. (1991), and other limited studies on this subject.

The amount of research that has been conducted on the major groups of organisms considered here varies widely. Although there are numerous publications on birds, mammals, and fishes in forested landscapes in the Pacific Northwest (see Appendix D), there is much less information on molluscs and arthropods. Information is lacking on distributions, abundance, and habitat relationships of amphibians, because they are not surveyed easily. The Forest Service's "Old-Growth Forest Wildlife Habitat Research Program" published by Ruggiero et al. (1991) presents an extensive data base on birds, mammals, amphibians, and plants in unmanaged forests of the Pacific Northwest. These studies provide a valuable information base on the abundance and habitat relationships of these groups of organisms in young, mature, and old-growth forests. However, similar information is needed on intensively managed forests at rotation age. In addition, information is needed on the response of plants and animals to various silvicultural prescriptions including selective harvests, uneven-aged management, long rotations, green tree retention, and snag management in these forests.

There is a lack of information on the taxonomy, distribution, and abundance of arthropods in different forest types throughout the Pacific Northwest. According to scientists at Oregon State University (Lattin and Moldenke pers. comm.), many of these organisms have not been described or named, and little is known about their distribution or abundance across the landscape and in different forest conditions. Likewise, definitive information on the distribution and abundance of molluscs in different forest types is lacking, and many of these species are sensitive to land use practices that alter the microclimates upon which they depend (Frest and Johannes 1991). Similar statements can be made about salamanders (Beatty et al. 1991).

Among the birds and mammals, several species are large and very mobile, and were not sampled adequately by the sampling designs of Ruggiero et al. (1991), nor have they been studied intensively elsewhere. More information is needed about their abundance and habitat relationships in various forest types and

their response to different silvicultural treatment. These species include the marbled murrelet, goshawk, Vaux's swift, fisher, marten, and wolverine. Other species, like the red tree vole, white-footed vole, and forest deer mouse are either rare or have behavioral traits that make them particularly difficult to study. These species should be the focus of further study, either individually or in community studies.

A number of other important research areas probably could be identified. However, the intent here is to highlight some obvious gaps in the information base on the relationship of plants and animals to different forest conditions throughout the Pacific Northwest. A more complete list of research topics could be developed by a group dedicated to this purpose.

Chapter VI

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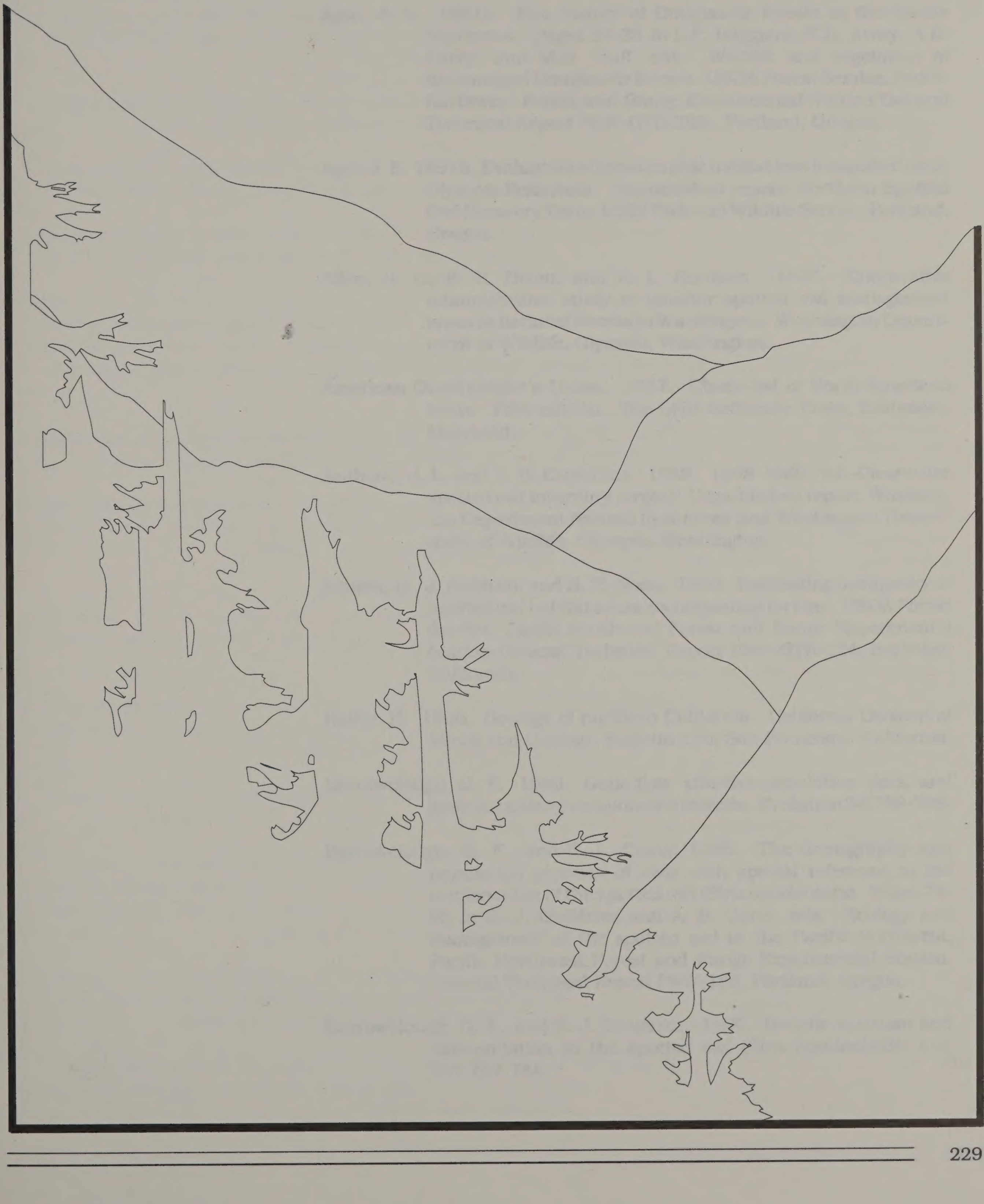

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Appendix A

Recommendations for Population Monitoring

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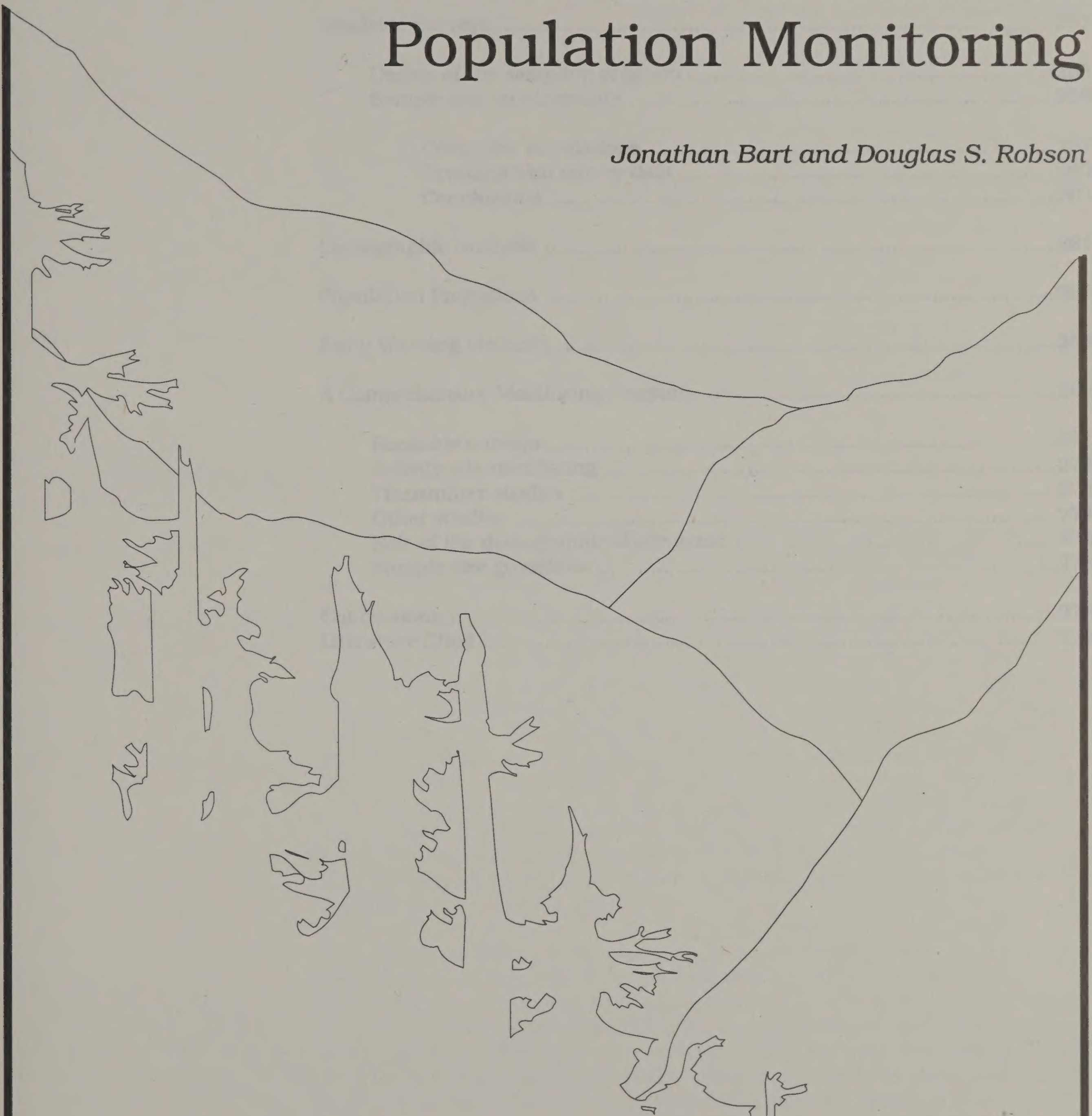

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Abstract

This appendix discusses methods for estimating or predicting population trends. Four approaches are discussed: roadside surveys of territorial birds, demographic analyses, population projections, and two "early warning" methods. Strengths, weaknesses, and requirements of each approach are discussed. The overall monitoring effort could be divided into five programs: 1) roadside surveys, 2) monitoring of activity sites, 3) transmitter studies, 4) other studies, and 5) coordination. Computer simulations and analyses of data from the Fish and Wildlife Service Breeding Bird Survey both suggest that a minimum of 8 years, and probably at least 10 years, of survey data probably will be required to obtain reliable estimates of long-term population trends. Delisting therefore should not be considered until at least 8 years of survey data have been collected. Preliminary estimates of sample size requirements suggest that an adequate sample of the roadside surveys could be obtained with less than 1 person-year of effort per state, and that approximately 5 person-years per state might be an appropriate level of effort for the program to monitor activity sites. These estimates do not include the costs of monitoring remote areas in wildernesses and national parks or continuation of the density studies , although these efforts are regarded as essential if the monitoring effort is to succeed. The program to monitor activity sites probably can be reduced or terminated after several years. The estimates in this appendix will need review and refinement, and are intended mainly as an incentive for further discussion and to provide reassurance that the monitoring program can be carried out at a reasonable cost.

Introduction

The sections in the body of the recovery plan on delisting criteria (section III.A.) and research and monitoring (section III.C.6.) identify many questions which should be addressed during the next several years. For example, more should be learned about what habitats, and how much of each, should be maintained in DCAs; proposals for modifying the recovery plan should be formulated and evaluated; and, at some time in the future, consideration should be given to delisting the northern spotted owl. In most of these issues, a need exists either 1) to estimate population trends, 2) to compare population trends in different environments, or, 3) to understand the factors that determine population trends. For some objectives, primary attention may be given to a single determinant of population trend (e.g., predation rates, productivity), but the overall goal of the recovery effort is to identify conditions under which owls will have a high probability of persisting, and predictions about persistence are difficult to make when only one factor that determines trends has been studied. Thus, monitoring or predicting population trends is one of the most fundamental objectives in the recovery plan.

This appendix discusses ways to estimate or predict population trends. Four general approaches are distinguished (Table A.1). First, *roadside surveys* involve counts of territorial birds present in an area. An index (e.g., call count) method may be used to estimate trends, or surveyors may attempt to find all territorial birds in a study area in which case absolute densities and trends of territorial birds can be estimated. Second, measurement of *demographic rates* involves estimating birth, death, and movement rates. Losses (deaths, emigrants) and gains (births, immigrants) are then estimated and compared to infer how the number of birds changed during the study period. This method permits inferences about trends in the total population, including nonterritorial individuals. Third, *population projections* involve finding secondary factors, such as habitat parameters, that can be measured and used to predict demo-

Table A.1. General approaches for estimating or predicting population trends.

1. Counts of territorial birds
   a. Trends in abundance
   b. Absolute abundance
2. Measurement of demographic rates
   a. Territorial birds
   b. Nonterritorial birds
3. Population projections
4. Early warning methods
   a. Age ratios among first-time territory holders
   b. Replacement times for territorial birds

graphic rates and population trends. Development of this approach could help researchers predict the effects of particular management strategies and might reduce the cost of monitoring populations by using habitat variables as a partial substitute for owl population variables. Fourth, two miscellaneous *"early warning" methods* for detecting a change in the number of territorial birds are described in this appendix. Neither method permits estimation of trends, but the data required could be collected relatively easily and would provide advance warning of imminent population declines in areas not well surveyed by the more sophisticated methods.

In the later sections, we describe each approach including its strengths and weaknesses and key research or design topics that should be investigated in developing the approach. We then identify overlap in the data needed for each approach and use this analysis as a basis for suggesting that the monitoring effort be divided into five programs. In a final section we provide preliminary sample size guidelines and estimate the amount of time needed before delisting should be considered.

We appreciate the help of the FWS Breeding Bird Survey program in providing data on short notice. Earlier drafts of this appendix were reviewed by Robert Anthony, R. J. Gutiérrez, Jesefa O'Malley, Edward Starkey, and Jerry Verner.

Roadside Surveys

One way to monitor owl populations is by counting all the owls in an area, or by using some of type of index method that, while not revealing actual abundance, provides a reliable estimate of trends in abundance. We refer to these as roadside surveys, although counts might actually be made from trails rathr than roads. Owl surveys routinely are made by nighttime or daytime calls. Unfortunately, nonterritorial birds seldom respond to the calls, thus this method only monitors the territorial population. Concern exists, that the overall population might be changing, and in particular that it might be declining, but territorial birds that died might be quickly replaced by nonterritorial birds. As a result, there might be little or no change in the

number of territorial birds even though the overall population was declining. Eventually, of course, the nonterritorial population would disappear and the territorial population would begin declining, but the true population decline could be masked for many years if only territorial birds were being surveyed (Franklin In Press).

Upper limits exist on the proportion of all birds that can be nonterritorial. The proportion is higher with high fecundity and juvenile survivorship. To investigate this issue, we prepared a computer simulation in which the demographic rates could be varied, and the nonterritorial population was allowed to reach equilibrium levels. With productivity (defined as number of female fledglings produced per territorial female per year) of 0.4, and survival rates of 70 percent in the first year and 90 percent thereafter, the model predicts population stability when about two-thirds of the individuals are floaters. With lower survival or productivity rates, the proportion is smaller. For example, with first-year productivity of 0.25, subsequent productivity of 0.35, first-year survival of 50 percent, second-year survival of 80 percent, and subsequent survivorship of 90 percent, the model predicts stability when about one-third of the individuals are nonterritorial.

Suppose that 60 percent of the owls in a population were floaters (i.e., nonterritorial), and the overall population began declining. If floaters immediately filled all vacancies in territories, then the population would decline by 60 percent before any decline in the territorial population occurred. Even with rather sharp, and perhaps irreversible, declines, an overall decline in population size of 60 percent would take many years. For example, if the population declined 5 percent per year, then 18 years would be required before the territorial population began declining. This example, while extreme, indicates the pitfalls of basing conclusions about population trends solely on programs that monitor the territorial population.

Despite these problems, surveying territorial birds is an important component of a monitoring program for several reasons. First, if declines in the territorial population occur, then we can be reasonably certain that the overall population is declining. Thus, decline of the territorial population does provide evidence of an overall decline even though the obverse is not true. Second, while it is possible that replacement of vacancies in territories by floaters might mask a population decline, this would only occur if floaters search for vacancies over a rather wide area. For example, if each nonterritorial bird fills any vacancy in a three-territory area, then if the population declines, some vacancies soon will begin to occur in areas where no nonterritorial birds of the same sex are present. Thus, the territorial population will decline, though at a slower rate than the overall decline. Third, this hypothetical problem caused by floaters only occurs if a substantial floater population exists; many areas may have only a few floaters, in which case surveys of territorial birds might faithfully reflect population trends. For these reasons, surveying territorial birds should be an important component of the monitoring program for spotted owls, even though it should not be the only method used to estimate trends.

Design of the sampling program

Several issues must be considered in designing the roadside survey program. We discuss some of these in this section. Throughout, we assume the purpose is to estimate trends in the territorial population, roughly defined as those birds that respond (or might respond) to owl calls.

An initial issue is whether the survey should be designed to provide census or index data. One possible design involves saturating each of several areas with survey stations and visiting each one many times, thereby obtaining a nearly

complete count of the territorial birds within the study area. The results might be thought of as "plot-type data" because within each study area all, or nearly all birds, are detected. Alternatively, "index methods" might be used in which no attempt was made to count all birds in any area. Results would be expressed as birds recorded per station or some other measure of effort, and investigators would assume that this measure had an approximately constant relationship to true density in the surveyed area. Under this assumption, changes in the index reflect changes in the population being surveyed. Thorough surveys give data less susceptible to substantial bias, but cost much more to collect. Index data are far less expensive to collect but may give biased estimates of temporal trends if detection rates change through time. Many areas, several of considerable size, probably will be searched thoroughly for territorial birds each year regardless of whether index or plot-type methods are used in the monitoring program. These data provides a basis for "calibrating" the index data by using a technique known as double-sampling. We describe this method below.

A double-sampling approach for monitoring territorial spotted owls might proceed as follows. First, areas to be searched thoroughly would be selected and delineated on maps. The main criterion for selecting these areas would be availability of surveyors willing to search the areas thoroughly (defined, for example, as searching to protocol). The areas could be large (e.g., demographic study areas) or small (e.g., single patches of old-growth) and would not have to be selected randomly, though random selection might be advantageous in some cases. Presence of a spotted owl within the area would be defined as occurring when the bird's activity center was within the thoroughly searched area. The assumption would be made that such searches constituted censuses of the territorial birds in the areas. The results would provide "true densities" for each area. Of course, in reality some owls would be missed, but such errors would have little effect on the estimate of trend if fewer than 10 percent of the birds were missed and this figure did not vary greatly among years. The thoroughly searched areas would be regarded as one stratum.

The next step in developing the program would be the delineation of additional strata. Strata could be defined to include DCAs and other high-interest areas, areas in which density is anticipated to be high, areas in which density is anticipated to be low, etc. The strata would not have to be contiguous; thus one stratum might consist of all the areas dominated by old-growth, another stratum might consist of all the areas with moderate amounts of old-growth, and so on.

Survey routes then would be selected using a well-defined random selection plan. For example, starting points for routes could be selected randomly and then the route could be laid out following predetermined rules. Efficiency (e.g., precision for a given amount of labor) would be maximized by (a) maximizing the number of different stations visited, and within this constraint, (b) maximizing the number of owls recorded. These principles suggest that each station should be visited at most once a year and that surveys should be conducted at a time and in a way that maximizes the number of owls recorded per hour of surveyor effort. Sampling intensity could vary among these strata so that more stations were located within areas of high interest, easy access, or high density. Sampling intensity in these strata could be determined subjectively, or they could be determined with formulas for maximizing statistical efficiency.

Each year, some or all of the randomly selected routes in these aditional strata would be visited and a random selection of stations (or routes) would be visited a single time in the censused stratum. Subsequent work would reveal the actual densities in the thoroughly searched areas, and these densities would

be used to calculate the ratio (result with the rapid method/actual density). This ratio then would be used to "calibrate" the index. One problem with this approach is that in double-sampling methods, the sample of sites searched thoroughly is usually a random sample from the entire population. This permits unbiased estimation of actual densities. In the case of spotted owls, the thoroughly searched areas have not been randomly selected. This may not cause serious problems, and even if problems do arise various ways can be found for resolving them. The issue, however, needs to be addressed before the final design is determined.

Another design question is whether all routes should be visited every year or whether some of the routes should be visited less frequently to increase the total number of routes included in the monitoring program. Visiting some of the routes less frequently than each year may be useful when the trend is small and when high within-site autocorrelation in successive years exists. An illustration of the design is shown in Table A.2 where some of the sites are visited only every third year while others are visited annually; such a design falls into the class known as "lattice sampling designs" (Yates 1960).

Formulas to estimate variance are available for these designs, and preliminary exploration of their implications for the roadside surveys suggests that these designs offer improved precision in trend estimation, and power in testing for trends, when compared to the design in which every site is visited every year. For example, in one simulation, a population declining at an annual rate of 3.4 percent was surveyed for 8 years. The simulation reports the probability of detecting this negative trend (i.e., power) with different numbers of stations visited per year and with different proportions of the stations visited only every fourth year. The results (Table A.3) showed that power increased as the number of stations visited only every fourth year increased. With 600 stations visited per year, power was 66 percent when all stations were visited each year and increased to 75 percent when all stations were visited every fourth year. The potential value of the lattice design is also evident by comparing sample sizes required to achieve a given level of power. For example, power was about the same with 800 stations, all visited on a 4-year schedule, as with 1,000 stations all visited each year. Thus, the lattice design, in this case, would permit a 20 percent reduction in the number of stations surveyed per year without any loss in power to detect the trend. Note, however, that the lattice design in this case would require the identification of 3,200 stations, rather than the 1,000 stations needed if all stations were visited each year.

The relative efficiency of the lattice design was even greater with longer survey intervals. For example, in another simulation involving a 12-year survey interval for a population declining at an annual rate of 3.7 percent, 1,000

Table A.2. Example of a lattice design in which four sets of routes are visited each year, one annually and the rest every third year.

Set	1	2	3	4	5	6	7	8	9	10	11	12
1	X	X	X	X	X	X	X	X	X	X	X	X
2	X			X			X			X		
3		X			X			X			X	
4			X			X			X			X

Table A.3. Power[a] for various designs of the roadside surveys.

Number of Stations Surveyed per Year	Proportion of Stations Surveyed Every Fourth Year[b]					
	0.00	0.20	0.40	0.60	0.80	1.00
200	0.32	0.33	0.34	0.35	0.37	0.38
400	0.51	0.53	0.54	0.56	0.58	0.60
600	0.66	0.68	0.69	0.71	0.73	0.75
800	0.77	0.78	0.80	0.81	0.83	0.85
1,000	0.84	0.86	0.87	0.88	0.90	0.91

[a]The probability of detecting the trend. In these simulations, the average proportional change in the population was -3.4 percent per year.
[b]The remaining stations were surveyed every year.

stations were required for 80 percent power when all stations were visited each year, but only 370 stations were required for the same power when all stations were visited at 4-year intervals. The lattice design thus requires that more routes be selected, but permits a smaller number to be surveyed in each year (to achieve a given power) than a design in which each route is surveyed each year.

The decision on whether to adopt a lattice design can be postponed until the second year of monitoring. At that time, a decision must be made to revisit every route surveyed in the first year or to temporarily drop some routes and introduce a corresponding set of new routes. If the new set were spatially interpenetrating with those that were dropped, then the logistics of the program would not be compromised by this tactic and the geographic dispersion of the sample would remain essentially the same. (Such a spatially interpenetrating design on a 4-year cycle is being implemented by the U.S. Environmental Protection Agency in its newly instituted Environmental Monitoring and Assessment Program, EMAP.)

Sample size requirements

Sample size includes the number of stations (or routes) monitored per year and the number of years during which monitoring continues. Many factors affect sample size requirements. Among the most important are the sampling design used to collect the data, the desired level of precision or power, and the degree to which the true trend conforms to the statistical (e.g., linear) model. At present, many of the factors needed to estimate sample size requirements for the roadside survey method are unknown. As a result, our analyses are preliminary and undoubtedly will be altered as more information is obtained. Despite these problems, the analyses provide an indication of approximate sample size requirements which will be useful in deciding on the initial specifications for the monitoring program.

Two analyses of sample size requirements are presented. The first is based on a series of computer simulations in which statistical methods were used to create data sets with known underlying trends. Estimates of these trends then were calculated and compared to the known, true values. The process was repeated with different parameter sets to investigate sample size requirements and identify factors that affect them. This analysis permitted a detailed investigation of sample size requirements but required an assumption that the computer model was realistic. For the second analysis, we obtained data from

the FWS Breeding Bird Survey on population trends in several species of hawks and owls. We calculated long-term trends and then estimated the number of years required to obtain reliable estimates of these trends. This analysis provides much less detailed results but involves real, rather than simulated, data. Each analysis provides useful information, but even in combination they provide only preliminary estimates of the sample sizes that will be necessary to obtain reliable estimates of long-term trends in spotted owl populations.

Computer simulations: This investigation required specification of an autocorrelation model describing the process by which the survey data would be obtained. The specific autocorrelation structure of the model is not critical, so an analytically tractable Markov chain model was used. The model in simplest form is defined by the probability ϕ that a site is initially occupied, the probability p that a site occupied in one year will be occupied the next year, and the probability r that a site not occupied in one year will be occupied the next year. These define a Markov chain on the two states of nature, "1" for occupied and "0" for unoccupied, as shown below.

Transition probability matrix

		Condition	
Initial probability	**Condition**	**1**	**0**
f	1	p	1-p
1-f	0	r	1-r

The expected proportion of occupied sites converges to a limiting value, $r/(1-p+r)$, independent of the initial fraction ϕ of occupied sites, so if the initial occupancy rate is less than this equilibrium value then an upward trend occurs. As an illustration of this phenomenon the trend over an 8-year period was calculated for the case p=0.9 and r=0.01 giving a limiting value of .01/.11 = .090909 for the fraction occupied after a large number of years. The initial fraction was chosen to be 30 percent smaller than this; namely, f = .070 (Table A.4). During the 8-year interval, this fraction increased 17 percent to 0.082, which is equivalent to an annual, proportional, or multiplicative, change of 1.019626 (i.e., $1.019626^8 = 1.17$). In the analyses below, we would describe such a change by stating that the population grew at an average annual rate of 1.96 percent.

Detectability bias and noise were introduced into the model by assuming that an occupant is detected with probability d, and "detection" is independent from site to site and year to year. Only "false negatives" are allowed; i.e., a true 0 is always recorded as 0 while a true 1 is sometimes (with probability 1-d) recorded as 0. This has the effect of i) reducing the expected slope by the factor d, ii) reducing the variance by the factor d^2 but iii) adding a noise variance component:

$$d(1-d)\Sigma c^2\, a$$

where c denotes the contrast year-coefficients and "a" denotes the yearly expected true-occupancy per site; i.e.,

$$\text{Expected sample slope} = d\Sigma ca.$$

Stochasticity in the transition probabilities p and r was introduced as random multiplicative effects. A year-specific, site-specific p became a product of a

Table A.4. Illustration of a Markov chain approach toward stochastic equilibrium when r/(1-p+r) is 30 percent higher than the initial fraction ϕ.

Year	Expected Occupancy
1	0.069930
2	0.072238
3	0.074292
4	0.076120
5	0.077746
6	0.079194
7	0.080483
8	0.081630

random year factor α, say, and a random site component τ, say, thus, $p=\alpha\tau$ where α is common to all sites that year and τ is common to all years at that site. Randomness in r was introduced by assuming that r/p is a random variable θ, $0<\theta<1$, for a fixed $p=\alpha\tau$; the distribution of α and τ were selected (from the beta family), for convenience of simulation, to be that of the largest order statistic of a sample from a uniform distribution on the unit interval, with the uniform sample size being chosen separately for α and τ to force the expected value of p to be a specified value (the same value as before when p was a constant). Similarly, the distribution of θ was taken to be that of the smallest order statistic from a uniform sample of a size determined by the previously assumed constant value of r. Such distribution choices enable the ready use of probability transforms in simulating values for α, τ and θ while also permitting some analytic calculations to be readily performed; e.g., the calculation of the vector (a) of expected annual occupancies.

The computer program permits power calculation for any combination of values for ϕ, p and r and for alternative lattice designs. The program will be more useful and informative after the first year of data is available to provide an indication of appropriate values for ϕ and r, but has been used in a preliminary exploration of sample size relationships for a variety of designs.

The model was used to generate 34 data sets. In each, a population changing in size at a specified rate was monitored for either 8 or 12 years, the probability of detecting the trend (i.e., power) was determined with different sampling designs and sample sizes. The level of significance was set at 10 percent in all tests. Rates of change varied from a decline of 4.8 percent per year to an increase of 4.5 percent per year; numbers of owls recorded per station varied from 0.03 to 0.14; detection rates varied from 0.5 to 1.0; and stochastic year and site effects were present in some analyses and absent in others. The number of stations visited per year varied from 200 to 1,000, and from none to all of them were on a 4-year cycle. Power varied from 0.21 to 1.00.

Power increased with increasing values of the following five variables: absolute trends, numbers of birds recorded per 100 stations, numbers of stations per year, number of years, and fraction of the station devoted to 4-year cycles. Detection rate and presence or absence of random factors in the simulation had little effect on power. The large number of factors having a substantial influence on power made it difficult to specify conditions required to achieve a specified power. In general, however, few simulations produced power of 80 percent when only 8 years of monitoring data were available. With annual

population changes of less than 3 percent and number of owls recorded per 100 stations of less than 10, power never reached 80 percent even when 1,000 stations were visited per year, all replaced annually (power was about 79 percent in this case). Higher absolute trends, or numbers of birds reported per 100 stations did push power above 0.80. For example, surveying 1,000 stations per year and recording 6.5 birds per 100 stations, when the population was declining 4.1 percent per year, produced power equal to 80 percent when 30 percent of the stations were replaced annually and 85 percent when all the stations were replaced annually. Despite these examples, in general, it was expensive, and sometimes virtually impossible, to achieve power of 80 percent with only 8 years of monitoring data.

With 12 years of data, many more situations were found in which power was above 80 percent, sometimes by a substantial margin. For example, with a 2.5 percent decline per year, and 6.2 birds recorded per 100 stations, power was 0.82 with 1,000 stations, all replaced annually. With 10 birds recorded per 100 stations, power exceeded 80 percent if 70 percent of 800 stations, or all of 600 stations, were replaced annually. With larger trends, smaller samples were sufficient. For example, with a 3.6 percent decline per year and 7.7 birds recorded per 100 stations, power exceeded 80 percent if 60 percent of 600 stations, or all of just 400 stations, were replaced annually. By contrast, if none of the stations was replaced, then 1,000 per year were necessary to achieve power of 80 percent.

Results from the simulations were analyzed with a general linear models program in which power was the dependent variable. The simplest equation with moderately high explanatory power was:

$$\text{power} = -1.18 + 0.04\text{stns} + 0.18\text{chg} + 0.04\text{recs} + 0.05\text{yrs} + 0.16\text{repl}$$

where stns = number of stations surveyed per year in 100s (e.g., 800 stations per year was coded as 8)

chg = annual percent change per year (e.g., if the population increased or decreased 3.2 percent each year then chg was 3.2)

recs = average number of birds recorded per 100 stations

yrs = interval length in years

repl = fraction of the stations on a 4-year cycle

The r^2 for this equation was 0.87. All variables were highly significant. Slight improvement was obtained by applying a square root transformation to several of the variables and including a few interaction terms but the gain (r^2 equaled 0.92 in the best model) did not seem worth the increased difficulty in interpreting the model. Adding detection rate and presence of random effects did not improve the fit of the model. The standard deviation and coefficient of variation of the residuals were 0.08 and 16 percent respectively indicating that the model revealed general trends, but did not make individual predictions very well.

The coefficients above, however, describe the general relationship between the variables and power. The general trend was to obtain an increase in power of about 0.04 for each of the following:

1. Increasing the number of stations per year by 100.
2. Increasing the annual trend by 0.25 percent (e.g., from 3 percent to 3.25 percent).
3. Increasing the number of birds recorded per 100 stations by 1.
4. Increasing the number of years on which the estimate was based by 1.
5. Putting an additional 25 percent of the stations on a 4-year cycle.

Obviously, these statements hold only for powers well below 1.0 and for appropriate ranges of the variables, and as noted above, the specific predictions of the regression model were often in error by 0.08 to 0.10 or even more. Nonetheless, the conclusions above provide at least a rough guideline to the ways that power is affected by altering the variables.

This analysis suggests that a minimum of 8 years probably will be required for 80 percent probability of detecting trends in owl populations unless such trends exceed 3 percent and more than 10 owls are recorded per 100 stations. Such a program probably would require that more than 1,000 stations be visited per year. If 12 years of data are available to estimate trends, then 600 stations per year, if visited on a 4-year cycle, might be sufficient to detect annual trends in the 2 to 3 percent range, particularly if eight or more birds are recorded per 100 stations. Obviously these conclusions are based on the assumptions inherent in the model, and these assumptions can be refined and improved as data from the monitoring program are collected. Furthermore, it must be remembered that these surveys do not detect trends in the total population; they provide information only about the territorial population.

Breeding Bird Survey data: Breeding Bird Survey data from a 25-year period (1966-1990) for hawks and owls were used as a surrogate for long-term spot-

Table A.5. Description of data sets used to estimate number of years required to obtain reliable estimates of long-term trends.

Species	State or Province	Years	Average Number Routes	Average Birds per Route	Percent Change	Autocorrelation[a]
Turkey vulture	Florida	1966-90	22	5.2	-1.4	1.99
	Maryland	1966-90	43	4.7	3.3	2.03
	Ohio	1966-89	24	1.5	3.1	1.50
	Oklahoma	1967-90	23	4.0	0.2	1.25⁺
Black vulture	Alabama	1966-90	28	2.1	2.1	2.56
	Florida	1966-90	21	4.7	0.1	1.78
Red-tailed hawk	Kansas	1967-90	29	2.1	1.1	2.07
	Oklahoma	1970-90	23	1.6	3.1	2.00
	Wisconsin	1966-90	57	0.7	4.3	2.18
Red-shouldered hawk	Florida	1971-90	23	2.0	0.9	3.01
American kestrel	New York	1974-90	46	1.4	-1.6	2.42
	Ohio	1974-90	24	1.3	1.4	2.38
	Ontario, Canada	1968-90	25	1.0	3.0	1.73
Osprey	Florida	1966-85	20	1.0	6.9	2.17
Great horned owl	Kansas	1967-90	29	0.7	2.2	2.48

[a]Based on Durbin-Watson test with a = 0.05;⁺ = autocorrelation present.

ted owl data. We used the following procedure to select several data sets, each consisting of the results for one species within one state or physiographic province. We asked the FWS for up to five data sets per species, each having 30 or more routes surveyed per year. They provided us with 31 data sets. We then discarded routes covered in fewer than 20 of the 25 years (inclusion of poorly covered routes can seriously bias trend estimates), and we discarded data sets in which this reduced the number of routes below 20. This process produced 15 data sets for analysis.

The 15 data sets included seven species and nine states or provinces (Table A.5). We calculated the mean number of birds per route recorded each year and plotted these means. Periods during which the long-term trends were approximately linear then were delineated by eye, and these intervals were used in the analysis. Most intervals were 20 or more years but two intervals were 17 years. The average number of routes per year (during the intervals used from each data set) varied from 20 to 57; the average number of birds per route varied from 0.7 to 5.2. The magnitude of each annual trend (referred to later as lambda, λ) was calculated using the same procedure as in the computer analyses described earlier (i.e., a λ of -1 percent meant that the population declined at an average annual rate of about 1 percent during the interval). The trends varied from 1.6 percent to 6.9 percent (Table A.5) and had an average value of 2.0 percent. Autocorrelation, as indicated by the Durbin-Watson test, was absent in all but one data set.

To determine how many years were needed to obtain reliable estimates of the long-term trends, we selected all possible sets of k sequential years (k = 3 to 15) from each period in each data set, calculated the estimated percent change per year and stored the error (estimated trend - true trend (i.e., $\hat{\lambda} - \lambda$). The data were summarized by determining the minimum interval length such that 80 percent of the errors were less than 0.02, less than 0.03, and less than 0.04. The rationale for this procedure was that the main source of concern in using this survey method is that the true trends not be seriously over-estimated. Our analyses give estimates of the sample size requirements when "serious" is defined as 0.02, 0.03, or 0.04, and the probability of avoiding this error is 80 percent.

The procedure is illustrated with data from red-tailed hawks in Wisconsin (Figure A.1, Table A.6). This data set showed an increasing trend throughout the 25-year period. The average annual change was 4.5 percent or 0.045. In the 25-year interval, there are 23 different intervals of 3 years each. An estimate of the "true," long-term trend (0.045) was calculated from each of these samples. Row one of Table A.6 indicates that 57 percent of these estimates were less than 0.02 higher than the true value (i.e., 57 percent were less than 0.065); 57 percent were less than 0.03 higher than the true value, and 61 percent were less than 0.04 higher than the true value. At the opposite extreme, 91 percent of the estimates based on 15-year intervals were less than 0.02 higher than the true value and all of these estimates were less than 0.04 higher than the true value.

Results such as these were compiled for each data set. We then estimated the minimum number of years needed for 80 percent probability that the error, $\hat{\lambda} - \lambda$, was less than 0.02, less than 0.03, and less than 0.04 for each data set (Table A.7). The results indicated that a minimum of 8 years was required for 80 percent confidence that errors in estimating trend were less than 0.02. With acceptable errors of 0.03 and 0.04, the corresponding figures were approximately 7 years and 6 years respectively.

There is little basis, at present, for deciding which of our data sets most closely resemble the data that will be collected for spotted owls. We studied the

Table A.6. Reliability of trend estimates for red-tailed hawks in Wisconsin as a function of interval length[a].

Number of Years in Sample	Percent of samples in which the error ($\hat{\lambda} - \lambda$)[b] was: <0.02	<0.03	<0.04
3	57	57	61
4	64	68	68
5	67	81	86
6	65	75	85
7	63	68	74
8	67	78	89
9	76	88	88
10	75	81	94
11	73	73	93
12	71	79	93
13	62	92	100
14	67	100	100
15	91	91	100

[a] Source: Breeding Bird Survey records 1966-1990.
[b] $\hat{\lambda} - \lambda$ = estimate of trend minus true trend.

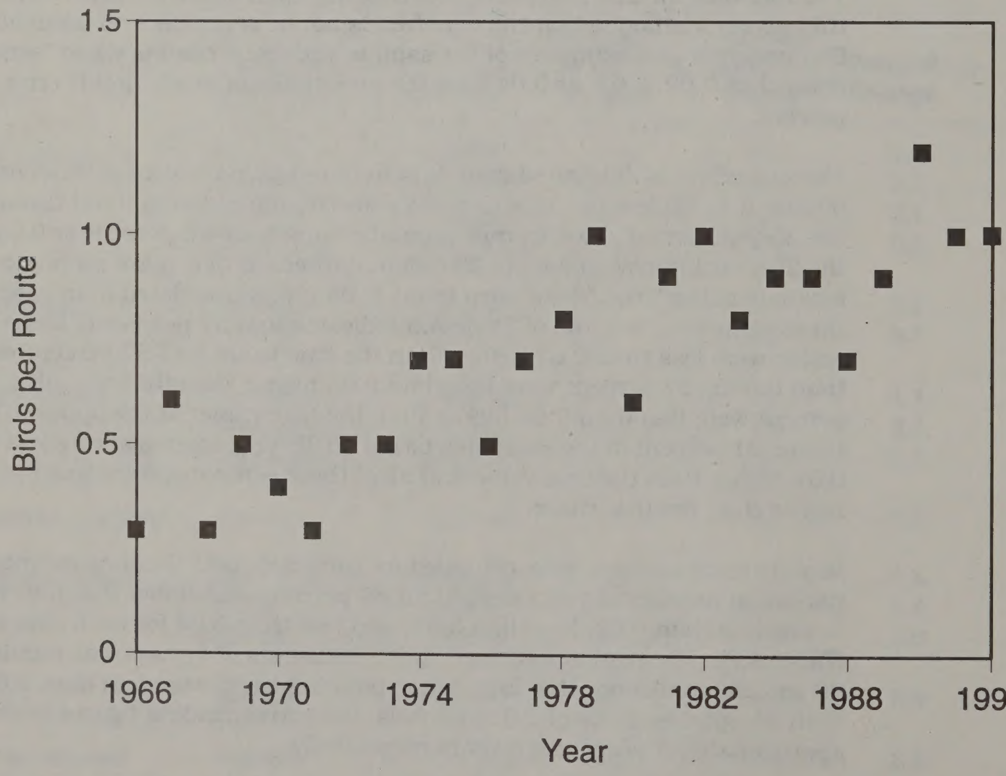

Figure A.1. Population trend for red-tailed hawks in Wisconsin as indicated by Breeding Bird Surveys data.

analyses to determine effects of sample size, outliers, and autocorrelation but were unable, with this small sample size, to reach definitive conclusions. Even if we had, it would probably be difficult to predict the form of the spotted owl data set. For example, survey data on diurnal raptors such as the red-tailed hawk that inhabits open landscapes might be considerably different from survey data for spotted owls. The analysis of Breeding Bird Survey data suggests that obtaining "reliable" estimates might take 7 years to more than 15 years, depending on one's definition of reliable and features of the data set. The analysis, while necessarily crude at present, provides no support for imagining that reliable estimates of trend could be obtained in fewer than 7 or 8 years.

Conclusions: We caution that these estimates provide only crude approximations of the sample size requirements, especially concerning number of years required for reliable trend estimates. As noted earlier, accuracy, for a given number of years of survey data, depends on many factors, none of which is well known at present for spotted owls. The analyses discussed earlier suggest that a minimum of 8 years probably will be required to obtain trend estimates reliable enough to be of any practical use, and the time certainly could be much longer, particularly if "bad years" have a pronounced effect on trends or if trends exhibit significant nonlinearity.

Table A.7. Number of years required to obtain reliable estimates of long-term trends from sample Breeding Bird Survey data sets.

		Approximate, minimum number of years for 80 percent probability that ($\hat{\lambda}-\lambda$) was:		
Species	**State**	**<0.02**	**<0.03**	**<0.04**
Turkey vulture	Florida	>15	9	8
	Maryland	12	7	6
	Ohio	15	15	5
	Oklahoma	1	10	9
Black vulture	Alabama	>15	13	10
	Florida	10	10	10
Red-tailed hawk	Kansas	8	7	4
	Oklahoma	14	8	7
	Wisconsin	5	13	6
Red-shouldered hawk	Florida	8	7	6
American kestrel	New York	8	6	5
	Ohio	8	8	8
	Ontario, Canada	13	10	8
Osprey	Florida	9	8	7
Great horned owl	Kansas	14	11	9

[a]$\hat{\lambda}-\lambda$= estimate of trend minus true trend.

Demographic Analysis

As noted earlier, one problem with estimating population trends based on counts of owls is that nonterritorial owls are essentially undetectable, so the overall population could be declining even if the counts did not indicate any decline. One way around this problem is to use estimates of birth and death rates to deduce whether the population is increasing or decreasing. This approach may avoid the problem of not being able to detect floaters, and it has the added advantage of providing insight into what factors might be responsible for population declines. For example, in comparing two areas, one with a stable population and one with a declining population, we might, by estimating demographic rates, learn that owl populations in the two areas had similar rates of productivity and juvenile survivorship, but that the declining population had a lower adult survival rate. This provides more information than we would obtain simply by monitoring territorial populations.

As a simple example of the approach, suppose we consider two consecutive years, beginning at the start of the breeding season (i.e., before any eggs have been laid). Let N_1 = the number of birds alive at the start of year 1, and N_2 = the number of birds alive at the start of year 2. Then, we may write,

$$N_2 = N_1 s_a + N_1 f s_j \qquad (1)$$

where s_a = proportion of the N_1 birds that survive until the start of year 2
f = average number of young fledged per bird alive at the start of year 1
s_j = proportion of the young fledged during year 1 that survive until the start of year 2.

Eq. (1) contains no assumptions; it is simply a way of expressing the empirical relationship between N_2 and N_1. Given eq. (1), we can also write

$$N_2/N_1 = s_a + f s_j \qquad (1)$$

so if we could estimate s_a, f, and s_j, we could estimate N_2/N_1, the proportional amount by which population size changed between year 1 and 2 (e.g., if N_2/N_1 = 0.95, then the population declined 5 percent between the start of year 1 and the start of year 2).

Now suppose we wish to estimate the average change for several pairs of years. We may write eq. (1) in the more general form

$$N_{t+1} = N_t s_{at} + N_t f_t s_{jt}$$

(t indicates year), and therefore,

$$\frac{N_{t+1}}{N_t} = s_{at} + f_t s_{jt}$$

The average annual change (with n pairs of years) is thus

$$\begin{aligned} \frac{1}{n}\sum \frac{N_{t+1}}{N_t} &= \frac{1}{n}\sum (s_{at} + f_t s_{jt}) \\ &= \bar{s}_a + \frac{1}{n}\sum f_t s_{jt} \end{aligned} \qquad (2)$$

Now, if f_t and s_{jt} are uncorrelated (which will be true if they vary independently of each other), then

$$\frac{1}{n}\sum f_t s_{jt} = \bar{f}\bar{s}_j \tag{3}$$

in which case

$$ave.\ \frac{N_{t+1}}{N_t} = \bar{s}_a + \bar{f}\bar{s}_j \tag{4}$$

so if we measured s_a, f, and s_j for several years (and if the correlation between f_t and s_{jt} was sufficiently close to zero) then the average change among years (λ) could be calculated as in equation (4).

Several practical problems arise in estimating λ for owls from demographic rates. Most of these problems are related to the fact that nonterritorial birds, and a few territorial ones, usually are missed during the surveys at the start of each year. Survival rates can be estimated from telemetry data but obtaining a large enough sample is difficult. As a result, capture-recapture methods must be used to estimate the survival rates.

Three common problems encountered in estimating population trends from demographic rates are described here. We discuss them with reference to the simple equation for λ described earlier, but note that in reality more complex equations generally must be used. Eq. 4, however, will suffice for illustrating the problems and providing a general indication of how much error these problems may cause in estimating λ. Before discussing the three problems, it may be helpful to define the terms above in more detail. We define these terms using all birds (i.e., males and females) whereas demographic analyses are usually based solely on females.

$$f_t = \frac{\text{no. fledglings produced in year t}}{N_t}$$

$$s_{at} = \frac{\text{no. of the } N_t \text{ still alive at the start of year t+1}}{N_t}$$

$$s_{jt} = \frac{\text{no. of the } f_t \text{ still alive at the start of year t+1}}{f_t}$$

1. Overestimation of $\bar{f}$.

   N_t includes all birds alive at the start of year t, but the number of fledglings per pair usually is estimated solely from territorial birds. Thus, N_t is underestimated and f_t is usually overestimated unless there are no floaters. One way to investigate this problem is by replacing $\bar{f}$ with $\bar{f}_g\bar{p}_g$ where $\bar{p}_g$ is the proportion of birds alive at the start of the year that are territorial and $\bar{f}_g$ is the average number of fledglings per territorial bird. Omitting $\bar{p}_g$ is equivalent to assuming that it equals 1.0. If it is less than 1.0, but is omitted, then population change is overestimated by the quantity $\bar{f}\bar{s}_j(1 - \bar{p}_g)$. For example, with $\bar{f} = \bar{s}_j = 0.3$ and $\bar{p}_g = 0.7$, the error would be 0.027, so if population change was actually 0.975,

the estimate (using the simple equation above and ignoring sampling error) would be 1.002. No one knows the true value for $\bar{p}_g$ but 0.7 is reasonable and serves to indicate the potential seriousness of this source of error.

2. Underestimation of $\bar{s}_J$.

   Some birds born in year t, leave the study area but survive until the start of year t+1. They usually are counted as having died which causes s_{Jt} to be underestimated. The significance of this problem depends on how many juveniles emigrate (and survive), which in turn depends on the size of the study area, intensity of searches outside the study area, and dispersal distances. If a proportion of the juveniles, p_{Je}, emigrates from the study area but survives at the same rate as those juveniles that remain within the study area, then $\bar{s}_J$ is underestimated (aside from sampling error) by p_{Je}, and λ is underestimated by $\bar{f}\bar{s}_J p_{Je}$. For example, if 20 percent of the juveniles leave the study area ($p_{Je} = 0.2$) and $\bar{f} = \bar{s}_J = 0.3$, then the error is 0.018. If the true λ was 1.00, the estimate (aside from sampling error) would be 0.982. Detailed studies that would permit estimation of p_{Je} for real study areas have not yet been carried out.

3. Temporary emigration.

   Because nonterritorial birds are seldom detected, young birds typically "disappear" for a few years and then reappear when they gain territories. The capture probabilities vary in exactly the way they would if the birds temporarily left the study area and then returned to it as adults. Such behavior violates the assumptions of capture-recapture models, and is known in capture-recapture literature as the problem of "temporary emigration." The problem is complex because its effects on the capture-recapture estimates are difficult to assess. Balser (1981) showed that emigration by some juveniles, who return to the study area as adults, causes over-estimation of the juvenile survival rate. The process with spotted owls is somewhat different because the period of temporary emigration (i.e., period during which the birds are nonterritorial) may last a few years into the adult age classes. Presumably, however, the behavior causes survival rates, particularly of juveniles, to be overestimated. As a result, λ would also be overestimated.

Despite these possible problems, measurement of demographic rates and calculation of trends from them, offer the only way at present to estimate trends in the whole population (i.e., both territorial and nonterritorial individuals) within a study area.

Use of these methods is illustrated in Appendix C which describes analyses of data from five demographic study areas. The studies provided data from 5 to 7 years and from approximately 300 to 700 birds. The confidence intervals for $\hat{\lambda}$ varied from approximately 0.04 to 0.09. These levels of precision were sufficient to show that the populations studied were declining, however considerably more data would be required to detect trends of 2 to 4 percent per year.

Population Projections

Various difficulties with the direct counts and demographic analyses as a means of estimating population trends have been identified earlier in this appendix. One additional problem with these methods is that they apply only to the area and period of time actually monitored. No rigorous basis is provided for predicting trends in the future or trends that would occur in hypothetical situations (e.g., under a proposed management plan). The simplest

ment of interest (e.g., the entire range). The model contains information about the environment, including the initial location of owls, and a series of rules governing births, deaths, and movements. These rules are used in a stochastic simulation of births, deaths, and movements during a year. At the end of the year, the locations of all owls are again recorded, and then they are used for the second year of the simulation. This process is repeated for as long a period as the user desires. The model permits up to six cell types, three age classes, and two sexes, with possibly different demographic rates. The rules for movements by juveniles and adults are flexible and permit simulation of a wide variety of behaviors. Additional details are contained in McKelvey (1991).

The Recovery Team convened an advisory committee of biologists to provide recommendations on the use of the landscape model. The committee compiled data of value in determining the parameters required by the model and made recommendations about certain structural changes. The advisory committee has not finalized recommendations, but intends to do so during the coming few months. Preliminary recommendations have been developed for habitat-specific productivity, juvenile survival rates, and adult survival rates for Washington and Oregon west of the Pacific crest and north of the Klamath provinces. The model appears powerful, flexible, and capable of realistic simulations. Considerable work is needed, however, to make the model operational. The following information is of particular importance:

1. Habitat specific productivity and survival.

   Preliminary estimates are available for portions of the range, but in other portions we do not have definitions for cell types. The needed information could be collected using two general approaches. First, home ranges of birds being monitored for productivity and adult survival should be assigned to cell types so that a sample for each type could be obtained. Second, intensive studies of transmittered birds should be made to improve our understanding of habitat types that are used and avoided. Study should also be made of the particular values to owls provided by each stand type. Much work of this sort has been done in western Oregon and Washington, but similar studies are needed (and in some cases are in progress) in environments east of the Cascades crest, in California, and in the Oregon Klamath province. Habitats of particular interest should be selected for these studies.

2. Effects of habitat on movements by dispersing juveniles.

   This topic has received little study but is critical for the evaluation of the recommended DCA network. Intensive monitoring of dispersing juveniles is needed to reveal how their movements and survivorship are affected by the configuration of habitat in the landscape they pass through, how widely they search for territories during dispersal, whether they settle in the first available place, and how far they travel if vacancies are not available. Close monitoring of a relatively small number of birds (rather than occasional location of a larger sample) is needed. Monitoring such a sample of dispersing birds, and analysis of the habitats and resident owls in their path, would provide a far better basis than we have at present for deciding on the values of the movement parameters in the landscape model. Such studies might be carried out in the density areas where the locations of other owls are already well known.

3. Behavior of nonterritorial adults

   Nonterritorial adults may buffer the population against loss of breeding adults if the floaters rapidly fill vacancies (Franklin In Press). At present,

however, we know little about the behavior of these nonterritorial birds, so determining their importance in maintaining stable populations is difficult. Monitoring a small sample of birds, perhaps followed continuously after being banded as fledglings, could provide much of the needed information. The critical question is how widely and continuously they search for vacancies in territories. Other issues, such as how their survival rates compare to territorial adults, should also be investigated.

As this information is obtained, it will be important to challenge the model with tests to reveal the reliability of its predictions. For example, predictions by the model of how dispersing juveniles will move across real landscapes can be compared with actual movements by transmittered birds. The environment in 1950, when public land was largely covered by old-growth and presumably had rather continuous populations of owls, can be reproduced in the computer and then altered during a 40-year simulation to resemble its current state. Distribution of owls at the end of the simulation then can be compared to actual distribution. Other tests of this sort can be carried out, to increase our knowledge of what the model can, and cannot, reveal about owl trends. Three broad outcomes of this work might be distinguished: the model may not make any reliable predictions, it may permit an "ordering" of trends under different proposals, or it may permit estimates of trends of sufficient accuracy to be useful. It is too early for confidence about how well the landscape model will perform, but it appears to have a better chance of predicting order, and perhaps absolute trends, than any other approach for modeling population dynamics of spotted owls.

Early Warning Methods

Two other methods for making inferences about population trends warrant consideration. Neither will provide reliable estimates of trends, but both may provide an "early warning" that population declines are imminent.

The first method is monitoring the age of first-time territory holders. The rationale of the method is that if the nonterritorial population is large, then many of the first-time territory holders probably will not be young (1- or 2-year-old) birds. However, if all adults hold territories then all first-time territory holders must be young birds (unless adults move after establishing a territory which is thought to be uncommon). These facts suggest that as the nonterritorial population declines, the proportion of first-time territory holders that are young birds eventually must increase to 1.0. Accordingly, monitoring this proportion might provide a basis for crude inferences about the nonterritorial population. If the ratio was 1.0 in one population and 0.3 in another, we might reasonably infer that the first population had more nonterritorial birds, and if the proportion began increasing, we might suspect that the overall population was declining even if the number of territorial birds remained stable.

The exact relationship between the proportion of first-time territory holders that are young and either the size of the nonterritorial population or the rate of population change appears complex and difficult to model. Computer simulations, however, can be used to indicate general trends. We have prepared such a simulation and used it to investigate the behavior of this age ratio. If nonterritorial birds are assumed to have wide "knowledge" of vacancies, and particularly if older birds are assumed to have a competitive advantage in filling vacancies, then the age ratio, in a population undergoing overall decline, remains rather constant until only a year or two before a decline begins in the territorial population. If each floater only fills vacancies occurring within a small area then the proportion drifts upwards much more slowly as population

size declines. In the former case, the age ratio would be of little value as an early warning sign, whereas in the latter case it could be of significant help.

Ages of first time breeders should be obtained for a series of populations, and the behavior of nonterritorial birds should be studied so that computer simulations can be made more realistic. The age ratio usually are obtained in the course of monitoring adult survival rates so this information can be obtained with little or no extra cost.

The second early warning method is the time that vacancies in the territorial population remain unfilled. Much the same argument as was made earlier can be applied to this variable. If a large nonterritorial population exists, then one would expect replacement times to be short, whereas eventually, as the population declines, some vacancies will not be filled at all. Thus, the replacement time should increase gradually as a population declines. Also, if nonterritorial birds search widely for vacancies, then the upward trend in replacement time might not begin until nearly all nonterritorial birds had disappeared, whereas if they search only locally, the upward trend might begin much sooner. This issue could be investigated to some extent by recording replacement times and tracking the change in their average value as a population changes in size. Empirical information about the behavior of nonterritorial birds, however, also would be of great value in understanding this variable and using its behavior to make inferences about population trends. This method would probably only work when some vacancies remain unfilled for at least a year.

A Comprehensive Monitoring Program

This section contains preliminary recommendations for a comprehensive monitoring program. The suggestions will need review and refinement, but enough information exists to develop the general outlines for the program. Considerable overlap exists (Table A.8) in the information needed by four approaches to estimate trends described earlier. For example, the "Demographic rates" approach and the "Population modeling" approach require information on productivity and adult survival rates, and information on the behavior of nonterritorial birds will be useful in population modeling and in the early warning approaches. Study of Table A.8 suggests that the monitoring effort might be subdivided into five programs (Table A.9).

The first program is the roadside surveys for territorial birds. Details of this approach have been described previously. The second program, activity site monitoring, would provide much of the information needed for demographic analyses and population projections. The difference in requirements of these two approaches is that demographic analyses require that sites be selected randomly and habitat information is not required, whereas population projections require that sites be selected in different habitats and habitat information is required. These differences can be accommodated by stratifying the range into habitat types and selecting sites randomly within each stratum. Specific habitat information about the sites also should be collected. Information collected at these sites (age ratios and replacements times) will provide much of the data needed for the two early warning methods. The third program is a series of transmitter studies. Studies are needed of dispersing juveniles and territorial and nonterritorial adults. As noted earlier, intensive monitoring is needed in some of these studies, even if this means that the sample size must be rather small. The fourth program includes miscellaneous studies that do not fit easily into the categories discussed earlier, and the fifth program is coordination of the first four efforts.

Table A.8. Summary of information needed for different approaches to estimating or predicting population trends.

1. Direct counts (information needed rangewide)
    a. Responses/stationon roadside surveys
    b. Actual density in several areas
    c. Responses on rapid survey in censused areas

2. Demographic analyses (information needed rangewide)
    a. Productivity
    b. Juvenile survivorship
    c. Adult survivorship

3. Population projections (information needed from selected areas)
    a. Productivity in relationship to habitat types
    b. Detailed data on juvenile dispersal
    c. Juvenile survivorship in relationship to landscape types
    d. Adult survivorship in relationship to habitat type
    e. Information on behavior of nonterritorial adults

4. Early warning methods (information needed rangewide)
    a. Ages of first-time territory holders
    b. Replacement times
    c. Information on behavior of nonterritorial adults

Table A.9. Proposed programs for collecting information needed to estimate or predict population trends.

1. Roadside surveys
    a. Estimate variance components
    b. Evaluate possibility of "road bias"
    c. Develop double-sampling approach
    d. Identify domains to study

2. Activity site monitoring
    a. Decide on stratification procedure
    b. Develop program for recording habitat information
    c. Provide training programs for participants

3. Transmitter studies
    a. Study juvenile survival
    b. Estimate natal dispersal distances
    c. Evaluate definition of "dispersal habitat"
    d. Study behavior of floaters
    e. Investigate effects of habitat on territorial birds

4. Other studies
    a. Investigate age ratios of first-time breeders
    b. Evaluate capture-recapture estimates
    c. Continue investigation of landscape model

5. Coordination
    a. Obtain commitments to carry out the program
    b. Organize centralized system for data processing
    c. Assess the role of the GIS

Each program is discussed briefly here. We review what information is needed, how much has been learned already, and what work should receive highest priority in the next few years. Much of this work is already in progress (though in most cases for purposes other than the development of a comprehensive monitoring program). As noted earlier, these suggestions are preliminary and will need considerable discussion and refinement.

Estimating or predicting population trends is the main objective of these monitoring programs, but the information they provide also could be useful in other aspects of the recovery program. For example, the roadside surveys could provide indications of relative abundance in young landscapes with and without remnant old-growth stands or individual trees. This information could be useful to silviculturalists studying ways to accelerate development of suitable habitat. In the following discussion, we attempt to identify some of these objectives and suggest how the monitoring program can be designed to help achieve them as well as achieve the primary goal of estimating or predicting population trends.

Roadside surveys

A great deal of effort already has been expended in developing techniques for calling owls, and these studies provided an excellent basis for designing the roadside survey. Little if any additional field work may be needed, but several analyses, discussed here, are needed.

1. Estimate variance components from samples of survey data.

   The computer program described earlier would provide more reliable predictions of power if estimates were available of the average number of birds recorded per station, and if the covariance structure in the data set was better defined, in different environments and portions of the range. The data needed for such analyses already have been collected, for example by the Forest Service monitoring programs and within the density study areas.

2. Estimate "road bias" and ways that it can be reduced.

   As noted in the description of roadside surveys, the savings in labor realized from restricting the surveys to roads (except in roadless areas such as wilderness areas) are so great that this approach probably should be followed in most areas. Numerous possibilities exist, however, for such a restriction to cause bias in trend estimates. For example, habitat is probably more fragmented near roads, may be more fragmented than far from roads, and population trends might therefore be different along roads and in the entire region. These possibilities can be assessed best by using the geographic information system (GIS) developed by the Recovery Team. It may be possible to stratify the range (e.g., into categories based on fragmentation) and to consider that *within strata* the roadside stations constitute a random sample.

3. Development of the double-sampling approach.

   Completion of the two tasks just discussed will provide the basis for final development of the double-sampling approach suggested for the roadside surveys. Estimates will be available of numbers of birds likely to be recorded per station in different strata and how these numbers will vary through space and time. This information can be used to develop more realistic formulas and simulations for estimating power and sample size requirements, and for suggesting allocation of effort among different strata. The result probably will be a program somewhat like the one used earlier to

predict the power achieved by different designs given numbers recorded per station, number of stations per year, and so on. The new programs would be similar, but would include the benefits gained from stratification and double-sampling.

4. What "domains" to obtain estimates for?

The term domain refers to a portion of a sampled population about which inferences are desired. A domain might consist of a certain province, DCAs of a certain type, or a certain environment. Domains may be redefined in different analyses; they do not all have to be identified before the analyses are conducted, and in reality, new domains are nearly always defined as the analysis proceeds. Much of the "art" in sampling involves trying to maximize the number of new domains of interest that can be constructed and studied after the data have been collected. The process, however, obviously is easier if the domains are specified during design of the sampling program. For spotted owls, domains of interest include provinces, states, DCAs, federal land outside of DCAs, and several different environments. The tentative list of domains to be studied in the monitoring program should be developed and used in making final sample size decisions.

Activity site monitoring

For this sampling program, the owl's range (including the demographic areas) would be subdivided into strata as in the roadside survey program. The strata could be different but there might be considerable advantage to having the same strata in the two programs. The sample size within each stratum would be determined, and areas would be chosen randomly (except for "censused" strata). The selected areas would be surveyed to identify all activity sites, and one or more sites would be selected randomly. These sites would be surveyed for some minimum number of years. Surveys would be conducted according to an approved protocol and the birds present at each site in each year would be banded so that turnovers could be identified. Productivity (number of fledglings produced) would be recorded, as would age of first-time territory holders and replacement times. Habitat information also should be collected about the activity site and surrounding area.

The major tasks needed for initiation and refinement of this program include the following:

1. Decide on stratification procedure and sample size requirements.

   Most of the comments made earlier about designing the roadside surveys apply to this program as well. Existing data on productivity, turnover rate, age ratios, and replacement times should be studied to obtain advance estimates of the parameter values and the covariance structure of the data. The possibility of roadside bias should be investigated. Domains of interest should be identified in advance, as much as possible, and the design should strive to accommodate the new domains that undoubtedly will be identified after analysis begins. Domains for the activity site monitoring may be defined using either landscape features or features of the habitat in the immediate vicinity of the activity site.

2. Develop a program for recording habitat information about the activity site.

   Standardized methods should be developed for collecting data on the habitat at the nest site and in the nearby areas. This work will involve deciding what areas around each site should be characterized, and what information should be collected. The information should serve the purposes of biologists

studying how demographic rates vary in different habitats and of silviculturalists studying ways to develop or maintain suitable habitat. Consideration should also be given to collecting information about habitat for other species.

3. Ensure that potential participants in the program have an opportunity to learn capture and banding techniques and obtain required permits.

   Training programs and assistance in obtaining required permits should be provided for potential participants in the program.

Transmitter studies

As noted earlier, studies are needed of dispersing juveniles and territorial and nonterritorial adults. The information provided by the studies will be useful in demographic analyses, populations projections, and in the efforts to model population dynamics, and in the "other methods" described earlier. The following investigations are particularly important.

1. Estimate juvenile survival and investigate the factors that affect it.

   As described in the section on demographic rates, biased estimates of juvenile survivorship, caused by emigration or nonterritorial status, are among the most troublesome problems in the estimation of trends based on demographic analyses. New, lightweight transmitters appear to offer the potential for estimating juvenile survival rates by following individuals birds (rather than via capture-recapture studies). One major study using this approach is underway in the Olympic Peninsula, and other similar efforts would be valuable.

2. Estimate natal dispersal distances and the factors affecting them.

   Natal dispersal distances, the straight-line distance between the birthplace and area of permanent settlement, provide a second way to evaluate the demographic estimates (by permitting an estimate of emigration rates), and will be of great help in evaluating the recommended DCA system. Dispersal distances of more than 100 juvenile spotted owls that survived to become territorial adults were collected recently. Study of this data set will aid our understanding of dispersal.

3. Evaluate and improve the definition of "dispersal habitat."

   The 50-11-40 rule is currently being used to define dispersal habitat, but biologists agree that more information is needed about dispersal habitat. The 50-11-40 rule probably applies better in some parts of the range than in others, other values for the three parameters might provide suitable dispersal habitat thereby giving managers a range of alternatives, and an entirely different definition of dispersal habitat (e.g., amount of old-growth remaining in the landscape) might be useful and appropriate in some cases. Understanding the requirements for successful dispersal probably will require intensive monitoring to determine what habitats are used, and for what purposes, by dispersing juveniles.

4. Study movements and behavior of floaters.

   This issue is critical in modeling population dynamics and in using the change in age ratio of first-time breeders as an early warning of imminent population decline. Perhaps the biggest obstacle in these studies is developing ways to capture nonterritorial birds so that transmitters can be at-

tached. If dispersing juveniles can be followed for long enough, some of them will be come floaters and possibly could be studied. Presumably they will be dispersed over a wide area, however, and there is some question about how many times they can be recaptured to replace transmitters. Other techniques may be needed.

5. Investigate how habitat affects survival and productivity of territorial birds.

   This information is needed for population projections, to define home range requirements, and to improve our ability to develop or maintain suitable habitat for owls. A great deal of information of this type has been collected in Washington and Oregon west of the Pacific crest and north of the Klamath province, and studies are underway, or have been completed recently, on the eastside of the Cascades, in the northern Klamath province, and in western California. Additional work is needed in the western part of the Klamath province and in the California Cascades. The results of these studies should be compiled and reviewed before decisions about additional work are made.

Other studies

A few studies that do not fit conveniently into the previously discussed categories also should be carried out. Most have been mentioned in the earlier parts of this appendix but they are reiterated here briefly.

1. Investigate age ratio of first-time breeders.

   The possible use of this parameter as an early warning sign of imminent population decline has been discussed. Efforts should be made to estimate this parameter from field studies and to understand how well it might indicate impending population declines through computer simulations.

2. Assess effects of small sample size on capture-recapture estimates.

   Possible biases in the capture-recapture estimates were mentioned earlier and are described in more detail in Appendix C. An additional concern is that capture-recapture estimates are known to suffer from small sample biases. These biases can be significant even with samples of several hundred individuals. The biases should be investigated through computer simulations to provide insights into their direction and possible magnitude.

3. Continue investigation of the landscape model.

   Several of the projects discussed earlier will provide data and insights of value in developing the landscape model. These data, along with currently available information, should be used to address the issues identified in the discussion of the landscape model. Determining whether the model faithfully reproduces patterns known to occur (e.g., dispersal patterns exhibited by transmittered birds, long-term population declines) is particularly important.

Coordination

A clear need exists for coordination and integration of the results from these studies. If different survey methods, different sampling techniques, and different ways of describing habitat are employed by field workers, then the overall recovery effort will be far less efficient in providing the information needed to refine the recovery plan and eventually delist the subspecies. The

coordination effort must ensure that methods are standardized and that rangewide sampling plans are followed. However, it must be recognized that different investigators have different objectives, and these may require different field methods and analyses. A few specific tasks, designed to accomplish this coordination, while not conflicting with the separate objectives of individual investigators, are identified below.

1. Obtain commitments to carry out the proposed surveys.

   The monitoring program proposed here can succeed only if the major federal and state agencies, and some of the major private landowners, agree to participate. The Recovery Team has convened a committee of agency and private biologists to develop the monitoring effort. Representatives to this committee should be formally appointed and authorized to represent their agencies and companies in making commitments to the monitoring program. Long-term commitments will be particularly important.

2. Organize a centralized system for obtaining and analyzing the survey results.

   Coordination of the monitoring effort will require numerous logistic efforts such as preparing data forms and mailing lists, entering data, preparing and running analytic programs, filling data requests, and preparing reports. The Recovery Team should take initial responsibility for this coordination and should sponsor a study to determine how long-term assurance of effective coordination can best be assured.

3. Assess the role of the GIS in the monitoring program.

   Many examples of contributions that the GIS could make to the monitoring program have been described. Obtaining GIS products, however, has often been difficult. The problems should be studied and resolved to the extent practical. The Recovery Team has arranged for assistance from U.S. Geological Survey in assessing GIS needs and capabilities, and additional efforts of this type should be made.

Role of the demographic study areas

The demographic studies will play an essential role in the monitoring effort as well as providing other critical information not directly related to monitoring. They will provide the data needed to "calibrate" the roadside survey and prevent biases due to changing detection rates, they may provide the best estimates of juvenile survival, and how it varies in different habitats, and they might be excellent sites for the transmitter studies. We assume that they will be continued and in some cases expanded. Consideration should be given to transforming them from owl studies into ecosystem study areas.

Sample size guidelines

Estimating sample size requirements is difficult until goals and design specifications have been determined more precisely. A few preliminary guidelines can be given for sample size requirements and allocation of effort among the various approaches discussed earlier.

Reasons for estimating trends can be divided into two broad categories: refinement of the recovery program and consideration of delisting (or upgrading to endangered status). Refinement of the recovery program will require numerous different estimates and studies, and estimating sample sizes for all of them is

impractical at present. We describe components of a monitoring plan that we believe would provide the data needed to estimate trends either for consideration of delisting or to gain assurance that serious declines would be detected.

One step in such an analysis is estimating the magnitude of fluctuations that might be expected in spotted owl populations that were stable and "healthy." No data for such calculations are available for spotted owls, but the estimates are important because we would not expect trends to be exactly zero, even if a population were fully recovered. In any given period, a population probably would be increasing or decreasing slightly and would have roughly a 50 percent chance of declining slightly. Thus, some effort must be made to understand the magnitude of trend that might be considered normal and to incorporate this information into sample size guidelines for the monitoring program.

We examined the Breeding Bird Survey data sets described earlier to help determine natural levels of variation in populations that are stable or close to stable. Four of the fifteen populations showed positive and negative trends during the 25-year period. We estimated both trends in these cases, obtaining a total of 19 trends. Five were negative and 14 were positive. About half (42 percent) of the absolute trends exceeded 3 percent per year and two-thirds exceeded 2 percent per year. The preponderance of positive values may have been caused by a slight overall increase in these populations at the regional or national level (Droege, pers. comm.) or perhaps by a general increase in surveyor skill (Peterjohn, pers. comm.). If we subtract 2 percent from all values, then 9 of the 19 trends (i.e., about half) are negative and half are positive. In this case, 37 percent of the absolute trends exceeds 3 percent per year and 42 percent exceeds 2 percent per year. These results suggest that average annual changes, over periods of up to 25 years in statewide populations of raptors, are commonly as large as 2.5 percent or 3 percent. Smaller populations probably exhibit somewhat stronger fluctuations, so annual changes in a single province of 3.5 to 4 percent may be common.

A second factor to consider in developing sample size guidelines is the cost of obtaining the estimate. Estimated sample sizes for detecting trends of 2 percent, 2.5 percent, and 3.5 percent, with either 8 or 12 years of data, are presented in Table A.10. They were computed initially from the general regression equation described earlier and were modified by inspecting tables of actual power as calculated by the computer simulations. The regression equation and the results in Table A.10 suggest that detecting a trend in 8 years takes 500 to 700 more stations per year than detecting the same trend in 12 years (compare adjacent columns in Table A.10). This guideline holds only if the trend during the 8-year period is linear. If trends are nonlinear then 8 years may be insufficient for estimating trends regardless of how many stations are visited per year. If 12 years of data are available for the estimate, then detecting trends of 2.5 percent would require approximately 800 stations (depending on number of owls recorded per 100 stations), and detecting trends of 3.5 percent would require approximately 300 stations per year. Similar calculations have not been carried out yet for the demographic analyses, but the confidence intervals for the estimated trend, based on 5 to 7 years of data, varied from 0.04 to 0.09 suggesting that 10 or more years would be required to detect trends as small as 2.5 percent, and longer might be needed if substantial year effects were present.

A final factor worth considering in developing sample size guideline is how the estimate of trend will be combined with other information in determining whether populations should be delisted. We believe that conclusions about the long-term stability of the population should not depend solely, or even primarily, on empirical estimates of trend. On the contrary, these data probably

should play a minor role, compared to efforts based more on *understanding the causes* of trends (i.e., population modeling). We believe the latter efforts will provide a more reliable and cost-effective way to estimate or predict trends.

The points discussed previously provide a basis for recommending sample size guidelines for the roadside surveys and demographic studies. Obviously, the initial choice may need revision as new information becomes available. We assume that 10 years of data will be available, and that both the roadside surveys and the demographic analyses should have an 80 percent chance of detecting annual changes of 2.5 percent at the statewide level or 3.5 percent at the province level. The analysis discussed earlier suggests that changes of smaller magnitude probably would be expensive to detect and hard to interpret since such changes may occur commonly in healthy populations. At present, such a guideline would lead to recommending that the roadside survey include visits to approximately 750 stations per year in each of the three states. Assuming that 15 stations are visited per person-day, the fieldwork would require 50 person-days per state or 10 to 15 days per province, a modest expenditure of effort that easily could be continued for many years. As noted earlier, detailed calculations have not been carried out yet for the demographic approach, but continuation of the density study area programs probably will provide the required statistical power.

Developing sample size guidelines for activity site monitoring is more difficult because the data collected during this work will be used for several purposes: demographic analyses, population projections, age ratios and replacement times. Objectives for these projects need to be specified before detailed sample size guidelines are developed for the activity site monitoring, but a few preliminary calculations may be helpful. Monitoring the sites will take several visits per season. If a total of 5 person-days were required per site, roughly 40 sites could be visited per-person year of effort. Thus 5 person-years of effort, for example, probably would be sufficient to monitor about 200 sites per year.

Most of the parameters estimated in the "activity site monitoring" program are proportions or can be treated as proportions to obtain approximate sample size requirements. In most cases, interest probably will center on comparing two proportions; e.g., productivity or turnover rates in two habitats. The standard error of a difference between two proportions depends on the proportions and, if data are collected in more than one year, on how much the difference between proportions varies among years. For this example, we will assume that

Table A.10. Preliminary estimates of the number of stations that must be visited per year to have an 80 percent chance of detecting trends.

	Average number of birds recorded per 100 survey stations:			
	8		10	
Trend	8 years	12 years	8 years	12 years
2.0 percent	-	1,150	1,400	850
2.5 percent	1,400	900	1,200	550
3.5 percent	1,000	360	800	250

the year effect can be ignored, and that formulas appropriate with simple random sampling are used in the analyses.

Little difference occurs in sample size requirements if the proportions are between approximately 0.3 and 0.7. Productivity (which can probably be modeled as a proportion since production of two female fledglings by a pair is reasonably rare) and the age ratio of first-time breeders are both probably in the 0.3 to 0.7 range. Suppose sites were visited for 5 years. The number of sites per group per year and associated 90 percent confidence intervals for estimated differences are approximately as follows: 50 sites, 0.09; 100 sites, 0.06; 200 sites, 0.044; and 400 sites, 0.031. For example, if 100 sites in each of two groups were each visited for 5 years, then the confidence interval for the difference would be approximately 0.044. Average productivities of 0.30 and 0.35, would be significantly different. In general, the sample size required to detect differences among groups would probably vary from 50 to 200 depending on the level of precision required. For estimating or comparing adult survival rates, a larger sample might be needed because, while the standard error is smaller with large probabilities, the difference one might wish to detect also would be smaller.

The brief analysis just discussed suggests that a reasonable target for the activity site monitoring program would be 200 sites per year in each state (40 to 60 sites per province). We assume that these would be in addition to sites in the density study areas. Such a program would permit numerous investigations of how productivity, adult survival, age ratios, and replacement times varied across habitats or other environmental features, across the range, and through time. The results would be of great value in developing the population modeling approach, they would probably be useful in the capture-recapture estimates, and they would provide confidence that populations were healthy or help identify problems if any occurred. The cost, 5 person-years per state for 5 years, seems acceptable in light of current expenditures for monitoring activities. We stress again, however, that these are "order of magnitude" estimates intended solely to give a first impression of how large the sample sizes should be. More detailed estimates can be provided after detailed objectives, and some preliminary results, are available.

Sample size guidelines for the other studies and cannot be provided until the specific objectives and methods have been identified.

Conclusions

The analyses and recommendations in this appendix are intended to provide a framework and a starting place for designing the monitoring program. Our main goal has been to demonstrate that such a program could be useful and could satisfy the requirement in the Delisting Criteria for a "scientifically credible sampling plan" at acceptable costs. Even if our estimates turn out to be low, it seems clear that the monitoring program described could be carried out at costs substantially less than those currently being incurred for spotted owl monitoring programs.

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Appendix B

Suitable Habitat for Northern Spotted Owls: An Update

Jonathan Bart and Susan Earnst

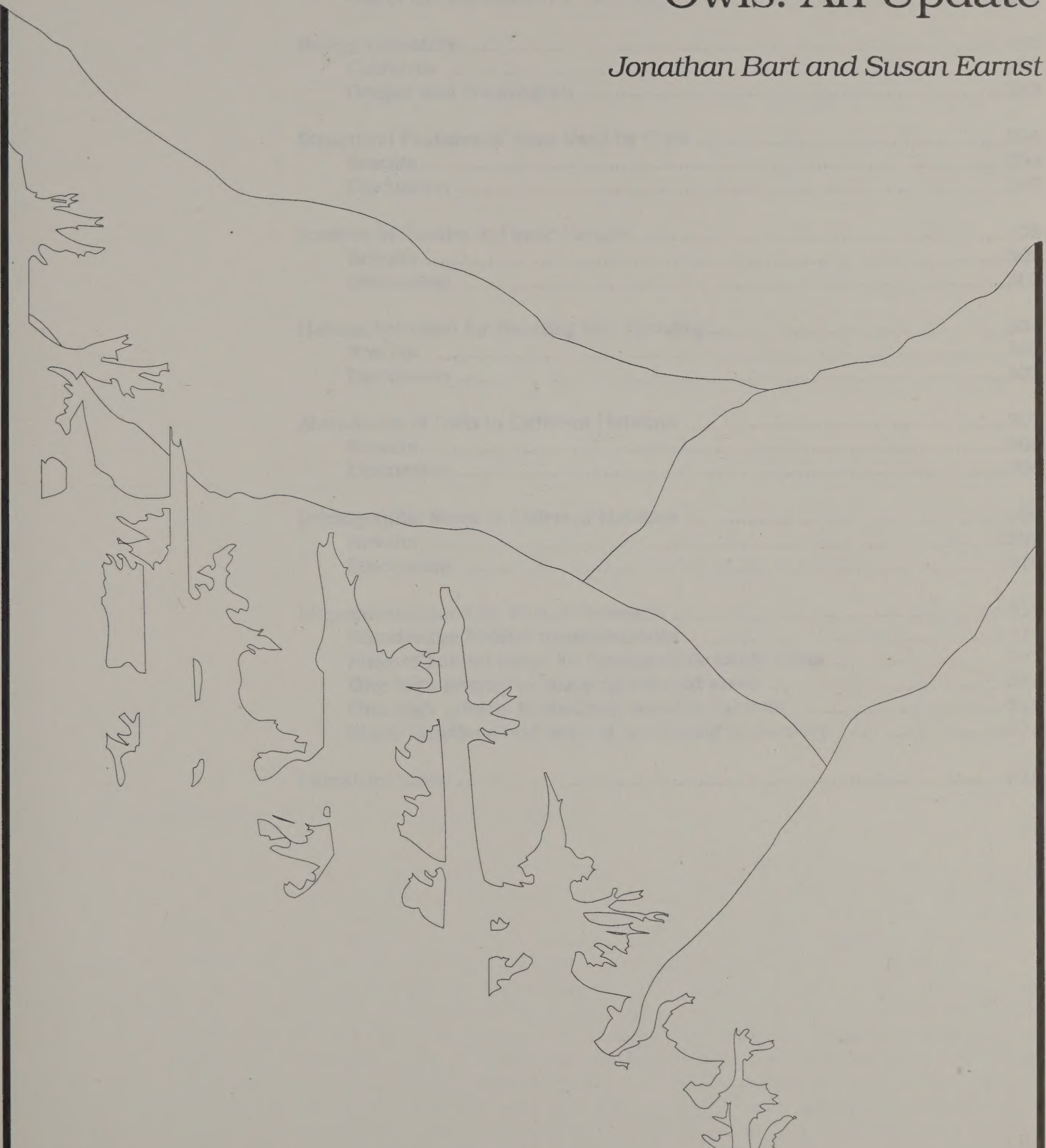

Table of Contents

Abstract

This appendix discusses the use of information on habitat suitability in the recovery program. Information on habitat suitability is divided into six categories: structural features of sites used by owls, amount of habitat in home ranges, habitat selection for roosting and foraging, abundance of owls in different habitats, demographic rates in different habits, and functional studies of resources needed by owls. Our current knowledge about each of these areas is summarized, emphasizing knowledge obtained since the review by Thomas et al. (1990). New information provides a clearer description of habitats used by owls and suggests that, as predicted by Thomas et al. (1990), a wider range of habitats may be suitable for owls in California than in Oregon and Washington west of the Cascade crest. New evidence also suggests that adult survival rates decline with decreasing amount of old-growth near to the nest. This finding is important because of the extreme sensitivity of population viability to adult survival rates. Recommendations for future work include standardizing habitat measurements, preparing habitat maps for the demographic study areas, and emphasizing new research in several specific areas or habitats.

This appendix summarizes information from habitat studies on northern spotted owls. Thomas et al. (1990) should be consulted for a comprehensive review of this topic; this appendix emphasizes studies which have appeared since Thomas et al. (1990). We discuss how habitat information will be used in the recovery program, review the state of our knowledge about suitable habitat for northern spotted owls, and offer tentative suggestions about priorities for future research on habitat requirements of owls.

We were assisted in the preparation of this report by Gary Benson, Randy Dettmers, Jeff Grenier, David Johnson, Jo Ellen Richards, Kristin Schmidt, and David Solis, each of whom analyzed studies and data bases describing habitat relationship of spotted owls in a portion of the owl's range. Reports by Benson (1991a,b) and Grenier (1991) are included in the administrative record of the Recovery Team. Bruce Bingham, Mark Boyce, Jennifer Blakesley, Charlie Brown, Joe Buchanan, Lowell Diller, Lee Folliard, Eric Forsman, Alan Franklin, Rocky Gutiérrez, Tom Hamer, Larry Irwin, Steve Kerns, Kevin McKelvey, Joe Meyer, Barry Noon, Malcolm Pious, Steve Self, and Cindy Zabel provided us original summaries and analyses of their data or pre-publication manuscripts. Previous drafts of the manuscript were reviewed by Bob Anthony, Edie Asrow, Gary Benson, Bruce Bingham, Lowell Diller, Alan Franklin, Rocky Gutiérrez, Richard Holthausen, Bruce Marcot, and Steve Self.

Studies of Habitat Suitability

Habitat suitability might be defined qualitatively as the degree to which a given habitat provides the resources owls need to survive, reproduce, and disperse successfully. No single definition captures all of the ways of measuring habitat suitability. For example, consider a study to determine the suitability of a particular habitat for foraging. Suitability might be assessed as the amount that foraging birds use the habitat, by capture rates per unit of time spent hunting in the habitat, by susceptibility to predators of owls foraging in the habitat, or by time required for the prey population to rebound after being depleted. Each of these measures would provide useful information and could legitimately be considered an aspect of habitat suitability. Habitat suitability is thus best considered an area of study, rather than a specific parameter. In a specific context, however, more precise definitions of habitat suitability may be reasonable. Furthermore, it is certainly possible to measure habitat features or attributes that have little or no relationship to the habitat's suitability for

owls. Consequently, the issue of whether a study has used good measures of suitability is important, even though we usually cannot provide a precise, quantitative definition of suitability.

Information from studies of habitat suitability will be useful in many parts of the recovery program. For example, habitats supporting self-sustaining owl populations should be identified and described, proposed conservation programs must be evaluated, models of owl population dynamics must have realistic descriptions of habitat relationships, and the structure of habitats that managers will attempt to develop and maintain must be described. In this section, we discuss the types of information needed for these assessments and predictions, and provide a brief evaluation of the ways in which each kind of information will be most useful in the recovery program.

Types of information collected

Studies of habitat suitability for owls may be divided into six broad categories:

1. Structural features of utilized habitats
2. Amount of suitable habitat in home ranges
3. Habitat selection for roosting and foraging
4. Abundance of owls in different habitats
5. Demographic rates of owls in different habitats
6. Studies of specific resources needed by owls

Studies describing structural features of utilized habitats present quantitative measurements of the habitats used by spotted owls for roosting and foraging. Variables reported frequently include dbh, canopy cover, and tree species composition. These variables, and others, may be reported for all trees or for overstory and understory. Separate analyses may be carried out for different activities such as nesting, roosting, and foraging, or for different periods such as breeding and non-breeding. Measures of central tendency (e.g., mean, median), variability (e.g., range, standard deviation), and precision (e.g., standard error, coefficient of variation) usually are presented for each variable measured.

Studies estimating the amount of habitat in home ranges generally have employed telemetry methods and the "minimum convex polygon" approach to delineate home ranges (see Thomas et al. 1990:193). A few studies have calculated the amount of habitat within some distance (e.g., 1.3 or 2.1 miles) of the nest. Lehmkuhl and Raphael (1991) investigated the use of this method on the Olympic Peninsula and found that it gave generally satisfactory results for habitat assessment. The habitats usually have been defined using size classes (e.g., old-growth, mature, pole, etc.) or age classes (e.g., more than 200 years, 120 to 200 years, etc.). Combinations of variables (e.g., mean dbh more than 21 inches and canopy cover more than 70 percent) have been used to define categories in a few studies.

Habitat selection for roosting and foraging has been assessed using telemetry methods to define home range borders and identify specific sites used by foraging or roosting birds. Investigators then compare the proportion of the locations in a habitat with the proportion of the home range covered by the habitat. Statistical analyses usually have been employed to determine which habitats (if any) were used significantly more often than would be expected if locations were distributed randomly with respect to the habitat types. Habitats used significantly more often than expected often are referred to as "preferred" and habitats used significantly less often than expected under the random distribution hypothesis often are referred to as "avoided." There is no implication of a state of mind, as is usually true when these words are used to de-

scribe human actions. Furthermore, results of the "use-availability" analysis provide no evidence that the features used to categorize habitats had any direct influence on owls; the features may have been correlates, rather than causes, of the preferences. White and Garrott (1990) provide a good discussion of use-availability analyses.

Studies of owl abundance in different habitats usually have employed index methods or intensive surveys to estimate relative or absolute abundance in two or more habitats. Few nonterritorial birds are detected on these surveys, so "abundance" means abundance of territorial birds, not all birds. This issue is discussed in more detail in Appendix A. The sample units in these studies generally have been survey stations, circles, or landscapes. Survey stations are assigned to the habitat category in which the station is located. Circles and landscapes generally are assigned to habitat categories based on the proportion of the sample unit covered by a particular habitat. For example, the habitat categories might be defined using percent of the sample unit covered by "older forest" (e.g., stands more than 80 years old). The categories might be 0 to 20 percent, 21 to 40 percent, 41 to 60 percent, and more than 60 percent. Alternatively, the habitat type may be regarded as a continuous variable (e.g., percent older forest). In either case, the investigation would provide information on the relationship between percent older forest and abundance.

Studies of owl demographic rates in different habitats generally have measured one or more of the following variables: proportion of territories with pairs, number of young fledged per pair-year, turnover rates of territorial adults, survival rates of adults, survival rates of juveniles. Turnover rates are defined as the proportion of adults disappearing from territories each year. Most of these analyses have been similar to studies of abundance except that the sample units have been pairs or territories (rather than plots) and demographic rates rather than abundance have been measured for each sample unit. The definition of habitat categories has followed the same process as in studies of abundance. A few studies (see Appendix C) have used estimates of birth and death rates, as well as rates of immigration and emigration, to calculate the rate at which population size changed during the study.

Studies of the specific resources needed by owls have investigated diet, prey base, nest sites, and home range size and composition. The objective in these studies is to identify the resources needed by owls for specific activities and to understand the processes that determine how well a particular habitat supplies these resources. These studies provide insights about the causes, rather than just correlates, of habitat suitability. The studies are reviewed in section II.A. of the recovery plan and are therefore not reviewed in this appendix.

It may be useful to recognize that the studies mentioned above provide descriptive, correlational, and functional information about habitat relationships of spotted owls. Measurements of structural features and amounts of habitat provide descriptive information about the environments where owls are found. Studies of habitat selection, density, and demographic rates provide correlations between habitat features or categories and measures of suitability (e.g., use, density, or demographic rates). These studies do not necessarily identify the features of importance to owls, so extrapolation to other environments may not be warranted. Studies of the specific resources needed by owls, however, help supply this understanding of causal relationships between habitat features and owl viability and thus greatly improve the reliability of assessments and predictions.

Use of the information

Assessments and predictions about the suitability of habitats for owls generally involve three steps:

1. Define habitats and habitat categories.
2. Determine suitability of each habitat category.
3. Evaluate basis for extrapolating findings to other populations.

The six types of information identified earlier play different roles in these three steps (Table B.1). Descriptive information about the structure of utilized sites and amounts of habitat within home ranges are particularly helpful in defining habitat categories. Knowing the amount of habitat present in home ranges also provides some indication of which landscapes provide suitable conditions. Correlational information provided by studies of which habitats are preferred for roosting and foraging, and by studies of density and demographic rates, are most useful in measuring the suitability of existing habitats. Correlational studies also provide some assistance in defining new habitats and deciding how much the results can be extrapolated to other populations of interest. Functional studies, in which causes are identified and distinguished from correlates, provide a good basis for measuring suitability and an excellent basis both for defining new habitat categories and for evaluating whether, or how well, the results of studies can be extrapolated to other populations. A few examples illustrating these generalizations and showing how studies of habitat suitability complement and reinforce each other are given later. More detailed discussions of how each type of information can be used in the recovery program are provided in subsequent sections.

Early surveys for owls revealed that density was high in areas with plentiful old-growth and low elsewhere. These descriptive and correlational results were supplemented by functional studies that sought to identify the specific resources needed by owls that were present in old-growth and absent in other areas. The results of the correlative and functional studies convinced most investigators that densities would remain low outside of old-growth. Since old-growth was expected to decline in abundance, this led to the prediction that overall populations would decline. In this example, the parameter indicating habitat suitability was abundance, and the habitat categories were old-growth and other. The critical assumption on which the prediction was based was that density would remain low outside of old-growth areas.

The landscape model discussed in Appendix A permits the definition of up to six habitat types, and the specification of various "rules" that define behavior and success of owls within each type. These rules are assumed to remain the same within each type through time. The parameters are thus the demographic rates and other rules followed by the model, and the habitats are defined by the investigator. Both correlative and functional studies are needed to define the habitat types, estimate parameter values within them, and evaluate the assumption that parameter values will be similar in study areas and areas about which inferences are made using the landscape model.

Owls are sometimes present in areas where most of the trees are fairly young (e.g., 50 to 80 years old), but some older and larger trees are present (e.g., Thomas 1990:184). This leads to the hypothesis that if some large trees were left during harvest, density of owls might increase substantially when the regenerating stand reached an age of 50 to 80 years. In this prediction the habitat is 50 to 80-year-old stands with remnant large trees, the parameter indicating suitability is density, and the primary assumption is that density in future habitats of this type will be similar to the existing habitats that have been studied. Descriptive and correlational studies were useful in developing

Table B.1. Roles and relative importance of different kinds of information about habitat suitability in making assessments and predictions about owl viability[a].

	Step in Making Assessments or Predictions		
Measure of Habitat Suitability	**Define Habitat Categories**	**Measure Habitat Suitability**	**Evaluate Basis for Extrapolation**
Structural Features of Utilized Habitats	XXX	X	.
Amounts of Habitat in Home Ranges	X	XX	.
Preference for Roosting and Foraging	.	XX	X
Abundance of Owls in Different Habitats	.	XX	X
Demographic Rates in Different Habitats	.	XXX	XX
Studies of Specific Resources	XXX	XX	XXX

[a] XXX = most important; . = least important

the hypothesis that retaining large trees creates suitable habitats. Functional studies are needed, however, to reveal whether large trees cause the high density of owls (compared to existing stands without large trees) or whether the large trees are simply correlates of some other feature that occurs in the existing habitats but might not occur as a result of the silvicultural manipulation.

Much of the effort in the recovery program will be devoted to identifying habitats that are "suitable" for owls at the stand, territory, and landscape level. All types of habitat study have contributions to make in this effort. Suppose, for example, that we have defined a habitat, call it Type A, that we believe might provide all of the resources needed by owls to maintain viable populations. We would first define the habitat using structural measures such as average dbh, canopy cover, and presence of a hardwood understory. We would then use several types of information to evaluate the hypothesis that Type A habitat was suitable for owls.

We might begin by examining the data from utilized habitats. Finding that utilized habitats frequently met our definition of Type A habitat, and that home ranges consistently contained large amounts of Type A habitat, would support the hypothesis. We would also examine data from correlational analyses. The habitat categories would be Type A and other. Strong preference for Type A stands would tend to support our hypothesis, as would a finding that density and demographic rates were higher in circles, landscapes, and territories with high amounts of Type A habitat. Results from functional studies would be useful in determining whether the specific features of importance to owls were highly correlated with the elements in our definition of Type A habitat and if they were, whether this was likely to be true in other environments to which we might wish to extrapolate our findings. We would not expect that all these tests and analyses to support the predictions, but if few of them did, then we probably would discard or substantially modify the definition of Type A habitat and start again. If most of the predictions were verified, then we would tend to feel that a good definition of suitable habitat had been developed.

A process very much like that above has been carried out in evaluating the hypothesis that older (i.e., mature and old-growth) forests provide suitable habitat for owls. Descriptions of utilized habitat have shown that nesting, roosting, and foraging owls usually are found in older stands and the structural features of these stands has been described in quantitative terms. Comparison of stands have shown that owls exhibit a strong preference for older stands for roosting and foraging. Reproductive success has been shown to be higher for pairs having more older forest in or near their home ranges. Density and adult turnover rates also have been shown to be positively correlated with amount of older forest in the landscape. Several hypotheses about the possible functions of older forest in supporting owls have been generated, and evidence supporting some of them has been reported. Thus, while no one piece of evidence would (or should) provide high confidence that older forest provides suitable habitat for owl populations, taken together these studies do provide such confidence. This of course does not mean that older forest is the only habitat that provides suitable habitat, but hypotheses predicting that other habitats also provide suitable habitat must be evaluated in the same comprehensive way that the hypothesis about older forest has been evaluated.

As the previous examples indicate, the results from descriptive, correlational, and functional studies are best used in combination, rather than in isolation. Descriptive information is most useful for defining habitat categories; correlational information at the stand, home range, and landscape level is most useful for measuring suitability of specific habitats; functional information is particularly useful for identifying the specific resources of value to owls and thus providing insights about how widely results can be extrapolated to other populations. Information from any single type of study would provide a poor basis for assessments or predictions about habitat suitability; taken together, however, they provide an excellent basis for such analyses. Subsequent sections explore in more detail the ways that each type of information contributes to analyses of habitat suitability.

Recent Literature

Thomas et al. (1990) provided a thorough review of the literature, including many pre-publication reports, available at the time of their report. Our discussion of habitat suitability is based largely on their review. Several reports have appeared since their study, and we have conducted new analyses of a few topics. The new studies, or studies from which we have extracted original data, are described briefly in the following section.

California

Asrow (1983) sampled the vegetation of four occupied spotted owl management areas (SOMAs) in old-growth Douglas-fir/white fir forests on the Scott River Ranger District of the Klamath National Forest. Owl presence was documented using a combination of night and day surveys during the 1983 breeding season. Vegetation was sampled on six variable-radius plots in each SOMA. One plot was centered on the location of the bird; other plots were placed 132 feet from the central plot and equal distances from each other.

Bingham (1991) described stands used by 20 radio-transmittered owls for roosting and foraging in Douglas-fir/tanoak/madrone forests on the Mad River Ranger District (Six Rivers National Forest) in the Klamath province. Utilized stands were defined as those with more than 3 telemetry locations. Data were summarized separately for roosting stands (based on daytime locations) and foraging stands (based on nighttime locations) in the breeding and nonbreeding season. Vegetation was sampled on 3 to 8 0.25-acre plots per stand. The author presented the data as means for each of three vegetation classes (defined on the basis of a cluster analysis); the data presented in this appendix are the means of these three classes, weighted by sample sizes.

Blakesley et al. (1992) recorded 421 owl locations, including 79 nest sites, during the breeding seasons of 1985 to 1989 in the Willow Creek study area in northwest California. Stand types were defined by dominant vegetation (conifers, hardwoods, unvegetated), mean dbh, elevation, aspect, position (lower, middle, or upper third), and slope.

Chavez-Leon (1989) measured habitat structure in 14 stands used by owls during 1987 and 1988 in the Klamath province (Humboldt and Mendocino Counties) in northwestern California. Pairs occupied nine and 10 sites in 1987 and 1988, respectively; nesting pairs occupied five and three sites in 1987 and 1988, respectively. Twelve of the 14 sites were in typical Douglas-fir/tanoak/madrone forests, and two were in redwoods. The landscape was highly fragmented; stands used by owls sometimes were fragmented and varied in size from 49 to 642 acres. Habitat structure was measured on five or more variable-radius plots randomly placed within each stand. Chavez-Leon excluded some plots in calculating mean densities and basal areas, but we used all plots for our analysis.

Folliard and Reese (1991) measured 30 nest sites and nest stands during 1990 in second-growth redwood/Douglas-fir forests of the California Coast province (Humboldt and Del Norte Counties). Plots were circular and covered 0.18 acres (radius = 50 feet). Nest-site plots were centered on the nest but did not include the nest tree in measures of density and basal area. Four or five plots were distributed randomly within 0.5 miles of the nest and in the nest stand.

Jimerson et al. (1991a) quantified the structure of old-growth Douglas-fir/tanoak/madrone stands in SAF 234 (i.e., Society of American Foresters forest type 234) in the Klamath province. Data were collected on the Six Rivers, Siskiyou, and Klamath (western half) National Forests, and the Northern California Coast Range Preserve. Vegetation was sampled on three variable-radius plots in each old-growth stand. Bingham and Sawyer (1991) presented a summary of this information.

Jimerson et al. (1991b) quantified the structure of old-growth Pacific Douglas-fir forests stands in SAF 229 in the Klamath province. Data were collected on the western half of the Klamath and Six Rivers National Forests. Vegetation was sampled on three variable-radius plots in each old-growth stand.

Kerns (1989) measured habitat structure at one roost site in each of 10 home ranges in redwood forests of the California Coast province (Humboldt County). The roost stands were in second-growth with few snags or old-growth trees remaining. Roost stands were considered "used" if an owl was present on more than one daytime visit; owls were present in most used stands during two or three daytime visits. Owl use was documented in 1988, and vegetation was sampled in 1989. One 0.5-acre vegetation plot was centered on the roost tree or, for smaller stands, in the stand (Kerns pers. comm.).

LaHaye (1988) measured habitat structure in six nest sites and stands in redwood forests of the California Coast province and in 38 nest sites and stands in the Klamath province (32 in Douglas-fir/tanoak/madrone forests, and six in mixed conifer forests of incense cedar/sugar pine/black oak). The nests were widely distributed throughout the owl's geographic range in California. Nest stands contained patches of remnant older trees that had escaped fires and other natural catastrophes, and in which the nests were usually located. The nest site was characterized by one plot centered at the nest tree and four plots located 75 feet from the nest tree and at equal distances from each other. Nest stands were characterized by plots at several distances from the nest. We used the data from four plots 450 feet from the nest tree and four plots 600 to 4500 feet from the nest. All plots were of variable radius.

Pious (1989) measured habitat structure on seven nest sites and 22 roost sites in coastal redwood forests of the California Coast province in Mendocino County. The sites were in second-growth stands in a landscape lacking any extensive, unharvested stands more than 200 years old. The location of roost sites was determined April-July 1989 through a series of nighttime calling surveys and daytime visits; the roosts were on 22 home ranges (Pious pers. comm.). Nest sites were described using two 0.17-acre strips placed perpendicular to one another and each centered at the nest. Nest stands and roost stands were described using two or three plots; each plot was a 0.25-acre strip, randomly placed within each stand.

Self and Brown (pers. comm.) described habitat structure on 21 nest sites in the Klamath province, in northcentral California. Most of the sites were located during the preparation of timber sales, and thus the surveys were concentrated in dense stands with large trees, rather than being fully representative of the landscape. The nests were in second-growth stands of Douglas-fir or Klamath mixed conifers (white fir, Douglas-fir, ponderosa pine, incense-cedar, and sugar pine). Most areas were under even-aged management regimes composed of a mixture of partial harvest techniques (selective, seed tree, shelterwood, thinning). All but one of the areas studied had some clear-cut regeneration harvests during the previous 10 years. Within-stand diversity was generally high due to the history of partial harvesting. Nest sites were described using two 0.17-acre strips centered on the nest tree.

Simpson Timber Company (1991) published a draft habitat conservation plan containing results of their owl monitoring and research program. Surveys to determine owl abundance, distribution, and reproductive success have been carried out annually on Simpson's land in the California Coast province since 1989.

Sisco and Gutiérrez (1984) and Sisco (1990) characterized the winter (October-February) roosting and foraging sites of five radio-transmittered owls during fall 1982 and winter 1983 on the Six Rivers National Forest (Humboldt County, California) in the Klamath province. Most home ranges were in Douglas-fir/tanoak/madrone forests, although parts of some home ranges at higher elevations were in montane forest (white fir, ponderosa pine, sugar pine, and incense cedar). Most roosting and foraging stands were unmanaged, although

the landscape and home ranges contained some stands under even-aged management. Roosting sites were visually located; sites with more than 5 nighttime telemetry locations were considered intensively used foraging sites. Twenty-seven roost sites and 200 foraging sites were characterized. Vegetation was sampled within a circular 0.1-acre plot centered on the roost tree or foraging location.

Solis (1983) and Solis and Gutiérrez (1990) characterized roosting and foraging sites of 10 radio-transmittered owls during the breeding seasons (February to September) of 1980 and 1981 on the Six Rivers National Forest (Humboldt County, California) in the Klamath province. Six of the owls were also studied by Sisco (1990). Fifty visually-located roost sites and 398 foraging sites were characterized. The habitat and sampling methods were identical to those of Sisco (1990).

Zabel et al. (1991) studied habitat use by spotted owls during the breeding and nonbreeding seasons in the Six Rivers and Klamath National Forests. Stand types were defined by dominant vegetation (conifers, hardwoods, nonvegetated), mean dbh, elevation, aspect, position (lower, middle, or upper third), and slope.

Oregon and Washington

Allen et al. (1989) described stands used by 18 radio-transmittered owls in nine spotted owl management areas on the Gifford-Pinchot, Mt. Baker-Snoqualmie, and Olympic National Forests. Douglas-fir, western hemlock, and Pacific silver fir were the major overstory trees. Vegetation was sampled at 436 intensively-used sites (i.e., sites with clusters of locations). At each site, 25 measurements were recorded using the point-center-quarter method. Most of the sites were in small stands of old-growth.

Benson (1991b) described stands used by six radio-transmittered owls in mixed conifer forests on the Wenatchee National Forest (Cle Elum Ranger District). Intensively used stands (those with three or more telemetry locations) within 0.5 miles of the nest were sampled with three to nine plots distributed uniformly in the stand. Each plot contained a variable-radius plot, a 0.20-acre circular plot, a 0.5-acre rectangular plot, and a line transect.

Buchanan (1991) characterized 62 nest sites and surrounding nest stands throughout the eastern Washington Cascades. Most of the nests were on the Wenatchee and Okanogan National Forests; a few were on private land. The forests were dominated by Douglas-fir and grand fir, with some ponderosa pine, western larch, western red cedar, and western hemlock, and with little hardwood understory. Median nest stand age was 130 years. Most young and mature stands contained remnant old-growth trees. Young had fledged at most of the nests within the previous four years, and only four nests had no record of successful nesting. Nest sites were described using a single 0.25-acre plot, and 4 0.1-acre plots, located within 110 feet of the nest tree. Nest stands were described using a single plot randomly placed within 1,300 feet of the nest tree.

Carey et al. (1991) conducted surveys for spotted owls (and other species) in 8 young stands (40-72 years), 10 mature stands (80-120 years), and 29 old-growth stands (200-525 years) in the southern Oregon Coast Range province. Surveys were conducted during April, May, or June in 1985 and 1986. The stands were visited approximately 7 times in each year. Average stand size was about 70 acres.

Hamer (pers. comm.) described 11 nest sites in Mt. Baker-Snoqualmie National Forest. Nest sites were described using a circular, 0.5-acre plot centered on the nest tree.

Meyer et al. (1992) studied relationships between habitat quality and various demographic measures on BLM land in southern Oregon and the border between the Klamath and Oregon Coast provinces. They selected 50 nest sites that each had been visited at least four times in each of 5 years. Habitats were defined using age and other features. Amounts of each habitat within 2.1 miles of the nest were measured. Several other variables (e.g., elevation, fragmentation indices) were also recorded.

Spies et al. (1988) quantified the stand structure in 85 old-growth Douglas-fir stands in the western Washington Cascades, western Oregon Cascades, and Oregon Coast Range provinces. Most study sites were in the Western Hemlock Zone and the lower elevation of the Pacific Silver Fir Zone; some sites were in the Mixed Conifer Zone and the Sitka Spruce Zone. Douglas-fir was the dominant species in all stands, although western hemlock was codominant in some stands. During 1983-1984, vegetation was sampled in five nested circular plots per stand, spaced 325 feet or 490 feet apart depending on stand size (range 10 to 50 acres). Nested plots included 0.1-acre, 0.25-acre, and 0.5-acre plots.

Structural Features of Sites Used by Owls

Relatively few descriptions of stand structure at owl sites were reported by Thomas et al. (1990). In the past 2 years, however, several new studies have appeared. We tabulated this information from studies in the Thomas et al. (1990) as well as from the more recent reports. Most studies recorded measurements at specific sites, as determined by radio-telemetry methods or by visually locating the bird. A few studies also recorded measurements from locations placed randomly with the stand. We refer to the latter as stand measurements; all other data in the tables are from specific sites used by owls.

We report average values from each study for abundance of trees by size class (all trees and hardwood understory), canopy cover, and abundance of snags. Where possible, results are presented separately for nesting, roosting, and foraging and for breeding and nonbreeding seasons. We emphasize that the range in values in our tables is not the range of average values on individual territories. Owls occurred in a much broader range of conditions than the range of values in our tables.

Many of the studies reported indicators of variability (e.g., ranges, standard deviations), but in most cases they were difficult to interpret because they depend strongly on plot sizes and sample sizes. The range (or standard deviation) of values from small plots generally will be larger than the range (or standard deviation) from large plots in the same area. Furthermore, many investigators combined plots across home ranges in calculating their measures of variability. The parameter (i.e., quantity of interest), in this case is difficult to describe in biological terms. We therefore report only the average values from each study, while recognizing that information on variability also would be of value.

Results

Klamath and California Coast provinces: Average canopy cover was 80 percent or more in all studies (Table B.2). The average number of trees/acre, by size class, also was quite consistent except for large (more than 36 inches

dbh) trees that varied in density from four to 14 per acre (Table B.2). No major differences were apparent between sites used for nests and sites used for roosting or foraging. Old-growth stands may have had slightly smaller average canopy cover than stands used by owls, however more detailed studies are necessary to reach firm conclusions.

Hardwoods comprised a large proportion of the trees less than 21 inches in dbh and a smaller proportion of the larger trees (Table B.3). Snags were rare in the studies in managed forests in the California Coast province (Folliard and Reese 1991, Pious 1989, Kerns 1989) (Table B.4). In the Klamath province, snags in stands used by owls occurred at average densities similar to densities in old-growth stands. The average density of logs appeared to be similar in the California Coast and Klamath provinces.

Three studies compared habitats used by roosting and foraging northern spotted owls (Table B.5). The studies provided data on canopy cover, size class distributions of live trees, canopy closure, and numbers of snags. No differences in the habitats used for roosting and foraging were detectable in these structural features. One study (Pious 1989) provided habitat data for both nesting and roosting/foraging (Table B.6), and no differences were detectable in the average number of large trees, canopy closure, or density of logs. More small trees were present in roosting sites than in nesting sites.

LaHaye (1988), Folliard and Reese (1991), and Pious (1989) compared measurements from nest sites and from throughout the nest stand (Table B.7). Average canopy closure, percent of trees that were hardwoods, and the densities of small and medium-sized trees were about the same in the stand and at nest sites. In the first two studies, fewer large trees were present, on average, in the stands than at nest sites. These data suggest that the owls in these studies selected average sites within stands except that utilized sites had more large (more than 36 inches dbh) trees.

Table B.2. Habitats used by northern spottd owls in the Klamath and California Coast provinces. Values are the means from each study.

Feature	Value	Nest sites		Roosting		Roosting and foraging		Nesting, roosting, foraging		Old-growth
Canopy		81[a]	86[b]			84[b]				
closure	%	92[c]	93[d]	84[e]	80[f]	91[g]	80[h]	95[i]	84[j]	65-80[l]
Trees/ac	5-10"	81[c]	69[d]	87[e]	92[f]	95[g]	124[h]	100[i]	75[k]	
by dbh	11-20"	51	65	37	39	36	42	60	-	
class	21-25"	23	19	17	18	15	14	14	-	
	>35"	7	4	8	7	14	11	5	13	

[a]LaHaye (1988) (average of values for Klamath and California Coast provinces)
[b]Pious (1989)
[c]Folliard and Reese (1991), and Diller and Folliard, (pers. comm.)
[d]Self, (pers. comm.)
[e]Bingham (1991) (Non-breeding season)
[g]Solis (1983)
[h]Sisco (1990)
[i]Chavez-Leon (1989)
[j]Asrow (1983)
[k]Kerns (1989) (Categories provided were 4-9" and "old-growth." Most of the old-growth trees were >36" dbh.)
[l]Bingham and Sawyer (1991)

Table B.3. Percent hardwoods in the understory (based on density) by dbh class at sites used by northern spotted owls in California.

Province	Approx. DBH (in)	Nest Site	Roosting		Roosting/ and foraging	Foraging	
California Coast	5-10	63[a]					
	11-20	50					
	20-35	18					
	35	0					
	11-24	51[b]					
	24-36	6					
	36	0					
	5-16	78[c]		68[c]			
	16	13		17			
	5-16			43[d]			
	16			13			
Klamath	5-10	31[e]	86[f]	73[g]	92[h]	68[f]	61[g]
	11-20	32	70	66	83	49	44
	21-35	19	22	43	44	17	27
	35	17	0	8	4	6	4
	5-10	-	58[i]	62[i]	9[j]	56[i]	62[i]
	11-20	77[b]	30	30	8	28	31
	21-35	30	10	9	2	8	9
	35	0	3	4	0	3	4

[a]Folliard and Reese, (1991); Diller and Folliard, (pers. comm.)
[b]LaHaye (1988) (intervals were 11-24", 25-36", and 36")
[c]Pious (1989)
[d]Kerns (1989)
[e]Self (1991)
[f]Solis (1983)
[g]Sisco and Guitérrez (1984); Sisco (1990)
[h]Chavez-Leon (1989)
[i]Bingham et al. (1991)
[j]Asrow (1983) (intervals were 1-10", 11-17", 18-29" and 30")

Other provinces: Fewer studies providing quantitative descriptions of utilized habitat are available from other provinces. Studies in the western Washington Cascades, Oregon Coast range, and Olympic Peninsula revealed approximately similar results for nest sites, roosting or foraging sites, and sites in old-growth stands, except that more large trees were found in the Olympic Peninsula than in the other areas studied (Table B.8). In the eastern Washington Cascades, fewer large and medium-sized trees occurred in nest sites, nest stands, and foraging sites than in the other provinces.

Maximum tree height was 103 feet in plots used for roosting and foraging in the eastern Washington Cascades (Benson 1991b). Spies et al. (1991) reported maximum tree heights in old-growth stands of 198 feet in the Oregon Coast province, 184 feet in the western Oregon Cascades, and 168 feet in the western Washington Cascades. Maximum tree heights have not been reported for stands used by owls in these provinces.

Total canopy closure averaged 83 percent for 11 nest sites in the western Washington Cascades (Hamer). In the eastern Washington Cascades, total canopy cover averaged 75 percent in 62 nest sites and 72 percent in the stands within which the nest were found (Buchanan 1991). In the same province,

Table B.4. Abundance of snags and logs in habitats used by northern spotted owls in the Klamath and California Coast provinces.

Feature	Province	Inches	Nest Site	Nest Stand	Roost	Roost/ Forage	Forage	Old Grwoth
Snags: no./ac. by dbh class	California Coast	>5	0[a] ~0[k]	0[a] ~0[k]	1[b] 3[a]			
	Klamath	>5	22[c]		16[d] 19[e] 30[f] 33[f]	16[g]	19[d] 18[e] 34[f] 35[f]	17[h] 21[i]
		>20			5[d] 2[f] 2[f]	1[g]	3[d] 2[f] 3[f]	2[h] 4[i]
		0-10				20[j]		
		11-18				2		
		>18				4		
Logs: no. ac by diameter at large end	California Coast	>10	59[a]	45[a]	53[a] 47[b]			
	Klamath	>10	55[c]		29[f] 31[f]	32[f]		
		>20			10 8	35[f] 10 8	12[h] 23[i]	

[a]Pious (1989)
[b]Kerns (1989)
[c]Self, (pers. comm.)
[d]Solis (1983)
[e]Sisco and Guitérrez (1984)
[f]Bingham et al. (1991)
[g]Chavez-Leon (1989)
[h]Jimerson et al. (1991a)
[i]Jimerson et al. (1991b)
[j]Asrow (1983)
[k]Diller and Folliard, (pers. comm.)

total canopy cover in roosting and foraging sites averaged 47 percent in six home ranges (Benson 1991b).

Only a few studies have reported snag densities (Table B.9) but densities appeared to be approximately similar in nest sites, nest stands, foraging and roosting sites, and old-growth stands, except that fewer medium and large snags were present in the eastern Washington Cascades province.

Log densities were similar in nest sites and old-growth sites in the western Washington Cascades (Hamer pers. comm., Spies et al. 1988).

Hardwoods were rare or absent in utilized sites in the western Washington Cascades, Olympic Peninsula, and eastern Washington Cascades (Allen et al. 1989, Forsman and Benson pers. comm., Hamer pers. comm.).

Discussion

The main results of this analysis were as follows. Average canopy cover was high (more than 80 percent) in all studies except those in the eastern Washington Cascades where average cover was lower at nest sites and much lower at roosting and foraging sites. The average number of trees/acre by dbh class was fairly consistent among studies, except that fewer large trees occurred in the eastern Cascades (in both Washington and California) and in the western

Table B.5. Comparison of habitats used by northern spotted owls for roosting and foraging in the Klamath Province of California.

Structural feature	Value	Solis (1983) Roost-ing	Solis (1983) Forag-ing	Sisco & Gutiérrez (1984) Roost-ing	Sisco & Gutiérrez (1984) Forag-ing	Bingham et al. (1991) Roost-ing[a]		Bingham et al. (1991) Forag-ing[a]	
Trees/ac by dbh class	5-20"	128	133	196	135	87	92	86	93
	20-35"	15	15	13	14	37	39	38	35
	>35"	16	12	10	11	17	18	18	17
						8	7	8	7
Canopy Closure	%	93	88	-	-	83	85	84	80
Snags/ac by dbh class	>5"	16	19	19	18	30	33	34	35
	>20"	5	3	-	-				

[a]First column is for breeding seasons; second column is for non-breeding season.

Table B.6. Comparison of habitats used by northern spotted owls for nesting and roosting in the Coastal Province of California .

Structural feature	Value	Nesting	Roosting
Trees/ac by dbh class	4-16"	140	229
	>16"	61	52
Canopy Closure	Percent	86	84
Logs/ac	>10" at large end	59	53

Source: Pious (1989).

Table B.7. Comparison of structural features at nest sites and throughout nest stands used by northern spotted owls.

A. Klamath and California Coast provinces (data from LaHaye 1988)

Sturctural feature	Value	Nest site	Nest stand
Canopy Closure	%	81	74
Trees per acre by dbh class	11-24"	63	42
	25-36"	17	3
	>36"	6	1
Basal area of snags by dbh	>15"	23	14

[a]ft2/ac

B. California Coast (data from Folliard and Reese 1991, and Diller and Folliard, pers. comm.)

Structural feature	Value	Nest site	Nest stand
Canopy Closure	%	92	94
Trees per acre by dbh class	5-10"	81	136
	11-20"	51	57
	21-36"	23	18
	>36"	7	2

continues—

B. *continued—*

Structural feature	Value	Nest site	Nest stand
% of live trees that were hardwoods	<10"	63	75
	11-20"	50	39
	21-36"	18	15
	>36"	0	0
Log volume by dbh class	15"	3208	2377

C. California Coast (data from Pious 1989)

Structural feature	Value	Nest site	Nest stand
Canopy closure	%86	87	
Trees/ac by dbh class	5-16"	140	193
	16"61	64	
% of live trees that were hardwoods	5-16"	78	58
	>16"	13	7
No. of snags per acre	>5"0	0	

part of the Klamath province in California. In all studies, the average number of trees decreased as diameter increased (i.e., in the "reversed J" pattern discussed in Appendix G). The hardwood understory was well-developed in utilized sites in California but was essentially absent in utilized sites elsewhere. Average snag density in utilized sites was similar to average snag density in old-growth sites except in the California Coast province where few snags occurred in utilized sites. Average values were similar for nesting, roosting, and foraging sites. No major differences were apparent between average values for sites and for stands containing the sites.

Review of Tables B.2 through B.9 indicates that information from California is much more complete than information from Oregon and Washington. The work by Allen et al. (1989) on roosting and foraging sites in the Olympic Peninsula and western Washington Cascades provinces and by Buchanan (1991) on nest sites in the eastern Washington Cascades are the only extensive studies yet reported. Additional information for Oregon and Washington will be available soon from studies currently in progress. Studies in the Oregon Klamath, Oregon Coast Range, and eastern Oregon Cascades provinces also would be valuable.

Table B.8. Tree density (number of trees per acre) by dbh class in Oregon and Washington provinces.

Province	dbh (inches)	Nest site	Nest stand	Roost/ Forage	Forage	Old-Growth
Oregon	3-9					54[a]
Coast	10-19					25
Range	20-39					17
	≥40					12
Western	3-9					62[a]
Oregon	10-19					33
Cascades	20-39					21
	≥40					12
Western	4-12	58[b]		94[c]	115[d]	
Washington	12-20	31		52	60	
Cascades	20-35	23		41	42	
	>35	10		23	14	
	3-9					64[a]
	10-19					34
	20-39					27
	>39					10
Olympic	4-12			89[e]		
Peninsula	12-20			33		
	20-35			36		
	>35			33		
Eastern	4-13	129[f]	117[f]			
Washington	13-23	35	29			
Cascades	23-33	16	10			
	>33	2	3			
			6- 9		59[g]	
			9-21		59	
			21-32		13	
			>32		3	

[a] Spies (1991)
[b] Hamer (1988) (dbh class definitions differed slightly those given; second size class was 11-20")
[c] Allen et al. (1989) (Mt. Baker-Snoqualmie National Forest)
[d] Allen et al. (1989) (Gifford-Pinchot National Forest)
[e] Allen et al. (1989) (Olympic National Forest)
[f] Buchanan (1991) and (pers. comm.)
[g] Benson (1991b)

Table B.9. Snag density (number of snags per acre) by dbh class in Oregon and Washington provinces.

Province	dbh (inches)	Nest Site	Nest Stand	Roost/ Forage	Old-Growth
Oregon Coast Range	>0				16[a]
	>20				7
Western Oregon Cascades	>0				25[a]
	>20				11
Western Washington Cascades	>0				30[a]
	>4	42[b]		33[c] 41[d]	
	>20	18		7 7	15
Olympic Peninsula	>4			25[e]	
	>20			10	
Eastern Washington Cascades	4-13	19[f]	13[f]		
	14-23	4	6		
	>23	2	2		
	>10			5[g]	
	>20			1	

[a] Spies et al. (1988)
[b] Hamer (1988)
[c] Allen et al. (1988) (Mt. Baker-Snoqualmie National Forest)
[d] Allen et al. (1989) (Gifford-Pinchot National Forest)
[e] Allen et al. (1989) (Olympic National Forest)
[f] Buchanan (1991)
[g] Benson (1991b)

This type of information is particularly useful in defining habitat categories. These efforts, however, must proceed with caution. For example, the results suggest that utilized sites studied to date tend to have trees of several different diameters (including some large trees), high canopy cover, and dominance by conifers, and that a hardwood understory is usually present in California but is not present in Washington and most of Oregon. As we have stressed, however, these generalizations describe average values in the study; they do not necessarily describe the features present at each site. Thus, birds might use some sites with a few large trees and few other trees but use other sites with no large trees but many smaller trees. This differential use might occur within or between home ranges. In either cases, the study-wide averages would be as reported earlier. Bingham (pers. comm.) has suggested that the values in Table B.10 may characterize utilized sites in mature stands but may not characterize utilized sites in old-growth stands very well. This suggestion could be investigated by comparing results for home ranges dominated by old-growth stands with home ranges dominated by mature stands.

Improved descriptions of utilized sites might be obtained by defining a habitat category using several habitat variables. For example, we might examine the study-wide averages reported in Tables B.2 through B.9 and then define a habitat category as including stands with canopy cover exceeding 80 percent

and numbers of trees, and percent of them that were hardwoods, as shown in Table B.10. We could then determine which fraction of the utilized sites in each study were in this category and which fraction were not.

In analyses of this sort, the parameter of interest must be specified with care, and the estimation procedure must take proper account of the field methods used to collect the data. The definition of "site" could have a substantial effect on the outcome of the study. Suppose, for example, that the acre centered on utilized sites always conformed to the description in Table B.10. If a few small plots were placed within the acre surrounding each site and means per plot were calculated, then many sample values would not conform to the descriptions in Table B.10 due solely to sampling error. This is a nontrivial problem (i.e., the errors could be quite substantial), and obtaining unbiased estimates of the proportion of acres meeting the definition would be a difficult statistical task. The analysis would be much simpler if plots and sites were defined to be the same size. Different studies, however, have used different numbers and sizes of plots so such an analysis cannot be performed using existing data.

Information on the structure of utilized sites also will be of value in guiding silvicultural efforts to develop or maintain suitable habitat and in minimizing adverse effects of harvest in the matrix. All of the cautions discussed earlier apply to such efforts, and it must remembered that these structural measurements provide little information about whether the sites provide suitable habitat because they do not relate structure to reproductive success of the owls. Even less basis is provided by these data for deciding whether other environments sharing some of the structural features might be suitable. Nonetheless, data on structure of utilized stands are an important first step in designing silvicultural programs that will be effective in helping protect owls.

Amount of Habitat in Home Ranges

Thomas et al. (1990) reviewed studies reporting territory or home range size, and amount of older forest within home ranges. This information is presented in section II of this plan (Tables 2.1 and 2.2) and will not be repeated here, but results from a few other recent studies are presented.

Results

Several recent studies in California provide additional information on the amount of one or more types of habitat within home ranges or circles centered on the nest or activity sites. These studies report the acreage within territories covered by stands with large (more than 21" dbh) trees. Solis and Gutiérrez (1990) found that eight summer home ranges in the Willow Creek study area (Six Rivers National Forest) contained a mean of 481 acres (range: 208 to 979) of this habitat. Zabel et al. (1991) reported that annual home ranges contained an average of approximately 900 acres of this habitat in the Six Rivers National Forest (Mad River District, 10 owls), 1,400 acres of this habitat in the Klamath National Forest (Ukonom District, nine owls), and 1,600 acres of this habitat in the Siskiyou National Forest (Chetco District, two owls). Self and Brown pers. comm.) reported that 21 pairs of owls had a mean of 503 acres of stands in which the mean dbh was more than 24 inches within 1.3 miles of their nest. Home ranges were not mapped by Self and Brown, but the home ranges studied by Solis and Gutiérrez (1990) were almost entirely within 1.3 miles of the nests, so the home ranges studied by Self and Brown probably had less than 503 acres. Not all nests studied by Self and Brown were in this habitat type and some home ranges contained no acres of this type.

Table B.10. Average values for characteristics of sites used by northern spotted owls in the California Coast and Klamath provinces.

dbh (inches)	Number of trees per acre	Percent of understory trees that are hardwoods
5.0 - 10.9	≥70	60-80
11.0 - 20.9	≥40	45-65
21.0 - 35.9	≥15	10-40
≥36	≥2	0-10

Table B.11. Relative use of stands with different tree sizes by transmittered northern spotted owls in the Klamath Province of California[a].

Season	Averages per bird	Average dbh >21"	5-21"	<5"	Open
Breeding	% of territory	42	31	27	-
(Mar-Sept)	% of locations	84	14	2	-
	% of locations/acre[b]	30	6	0.4	-
Non-breeding	% of territory	45	30	11	2
(Oct-Feb)	% of locations	56	30	11	2
	% location/acre[b]	16	8	8	8

[a]Data from Solis (1983) and Sisco and Guiterrez (1984).
[b](% of locations in habitat "x")/(number of acres of habitat "X")

Discussion

Studies summarized in Thomas et al. (1990:195) show that considerable variation exists within provinces in the amount of older forest in annual home ranges. The ratio maximum:minimum amount was 15.4 in California, 3.5 in the Oregon Klamath province, 5.7 in the Oregon Coast Range, 10.7 in the western Washington Cascades, and 3.0 in the Olympic Peninsula. In California, some of the nests studied by Self and Brown (pers. comm.) had virtually no stands with mean dbh more than 24 inches.

Several explanations for the large variation in amount of older forest within home ranges are possible, and they have different implications for the recovery program. In general, the variation does not cause too much concern about how well DCAs will function, but does cause considerable concern about guidelines for avoiding "take" that suggest preserving amounts of habitat around individual pairs that equal the median amounts that have been recorded in home ranges. This point is illustrated the by following hypotheses to explain the high degree of variation observed in amount of habitat within home ranges.

1. Owls with more older forest had higher fitness.

Under this hypothesis, owl fitness is a function of the quantity of habitat. It is possible that only those owls with the most older forest reproduce and survive at replacement rates (or higher). In such a case, preserving the median amount of older forest around single pairs might not permit any of the pairs to survive and reproduce at replacement rates. In contrast, using the median amount to decide how large a DCA should be would be appropriate. Some home ranges would be larger than the median, some would be smaller, but the cluster as a whole reasonably could be expected to sustain itself.

2. Quality of the older forest varies (e.g., in density of prey and growth rate of prey populations).

   Under this hypothesis, the amount of habitat needed to support a pair of owls varies among home ranges. In some areas, 1,000 acres of older forest might be needed for owls to survive and reproduce at replacement levels; in other areas, 2,000 acres might be needed. If owls actually use the amount they need, and we preserve the median amount around individual pairs, then only half the pairs will be provided with the amount of habitat they need for replacement levels of productivity and survival. As in the first hypothesis, this is not too serious in designing DCAs because the owls will delineate home ranges to take account of the variability in habitat quality.

3. The definition of older forest includes unsuitable habitat and/or excludes suitable habitat.

   Under this hypothesis, the definition of suitable habitat is a poor predictor of real habitat suitability. For example, fragmentation or number of canopy layers might affect quality of habitat but might not be parts of the definition of suitable habitat. In this case, defining older forest as any mature or old-growth stand might lead to preserving either more or less than the amount of habitat needed by owls to survive and reproduce at replacement levels. If DCAs are placed where owls are present and viable, then the poor knowledge of what actually constitutes suitable habitat would be much less serious.

These examples are intended to emphasize that the large variation in amount of older forest within home ranges raises concerns about our current ability to decide which habitat, and how much of it, should be protected around individual pairs to ensure that they can survive and reproduce at replacement levels. The uncertainty is less serious for construction of the DCAs, particularly because they are generally constructed around known pairs.

Considering the large variation in amount of habitat within home ranges, there is some question about the value of additional studies that report this figure unless these studies also provide information about how the habitat is used or how successful the owls in the home ranges are. Future work should probably combine estimates of home range size and amounts of older forest present with more detailed stand descriptions, measures of viability, and functional studies to examine how different stands are used.

Habitat Selection for Roosting and Foraging

Thomas et al. (1990:143-170) reviewed the literature on use of habitats, categorized by successional stage, for roosting and foraging. In Oregon and Washington, west of the Cascade crest, old-growth stands were consistently preferred for both activities. Results were mixed for mature stands. Young stands, pole stands, and other stands were consistently avoided. Old-growth

stands were defined as being more than 200 years old in most studies. Mature stands in most of the studies were 80 to 200 years old and even-aged (or had "few canopy layers"), and had mean diameters of approximately 21 to 39 inches. More recent work is summarized in the following sections.

Results

Several recent studies in California have analyzed habitats defined by mean dbh of the stand. Some of these studies have used the following definitions: seedlings and saplings: less than 5 inches; pole timber: 5 to 10.9 inches; small timber 11 to 21 inches; mature and old-growth: more than 21 inches. Other studies have combined the two middle categories and have defined the following categories, referred to as seral stages: early successional (less than 5 inches), mid successional (5 to 21 inches), and late successional (more than 21 inches).

Solis and Gutiérrez (1990) and Blakesley et al. (1992) studied habitat use by owls during the breeding season at the Willow Creek study area. The seven birds studied by Solis and Gutiérrez showed a clear preference for mature and old-growth stands (Table B.11); 84 percent of the locations were in large-diameter (more than 21 inches dbh) stands and small-diameter (less than 5 inches) stands were almost never used. Blakesley et al. (1992) found that virtually all roost locations were in the 11 to 21-inch dbh and more than 21-inch dbh categories, and the number of locations per acre of habitat was nearly twice as high in the more than 21-inch stands as in the smaller stands.

During the nonbreeding season, the situation was more complex. Sisco (1990) found little or no preference for particular stands (Table B.11). Only 56 percent of the observations were in mature and old-growth stands, and small diameter stands were used roughly in proportion to their abundance. As shown in Tables B.2 through B.5, however, the average structural features of sites used by these birds were similar in the breeding and nonbreeding seasons. It thus appears that during the nonbreeding season, the owls used stands roughly in proportion to their availability but they selected sites within these stands that had larger-diameter trees. Blakesley et al. (1992) noted that the 11 to 21-inch dbh stands in this study area have resulted from natural processes and are more variable than plantations of the same mean diameter. This study should not be taken as indicating that 11 to 21-inch dbh plantations in this area would provide adequate habitat for owls during the nonbreeding season.

Solis (1983) and Solis and Gutiérrez (1990) also presented data on use of habitats categorized by overstory and understory canopy coverage. Stands in which both the overstory and understory canopy cover exceeded 70 percent had more use than stands with a less well-developed overstory and much more use than stands with a poorly developed overstory and understory (Table B.12). These birds thus concentrated their activities in stands having high canopy coverage in the overstory and understory.

Zabel et al. (1991), working on the Six Rivers and Klamath National Forests, found only slight tendencies by owls on either forest to select particular stand types, categorized by either mean dbh or canopy cover (Table B.13). Only half the owls showed significant selection for any habitat (i.e., chi-square analysis rejected the hypothesis of random distribution), and patterns of use varied between owls. In the Klamath National Forest, owls showed slight preference for 21 to 36-inches trees, but no preference for trees more than 36 inches. In the Six Rivers National Forest owls showed no preference for 21 to 36-inches trees and slight preference for more than 36 inches trees. Stands were also divided into those that did and did not meet the Forest Service definition of

suitable habitat for that region (more than 21 inches dbh, more than 20 percent dominant canopy cover, and more than 70 percent total canopy cover). A use-availability analysis showed that 69 percent of the owls showed significant preference for suitable habitat during the breeding season and 39 percent did so during the nonbreeding season. The authors concluded that habitat preferences were exhibited for stands with large trees and high canopy cover, but that the preferences were weaker in this study than in other studies.

An example in which owls may *not* have avoided more open areas is provided by Kerns (1989) who studied radio-transmittered birds in managed stands in the California Coast province. He monitored three birds during the breeding season, obtaining 94, 95, and 151 locations. Habitat in the area used by each

Table B.12. Relative use by northern spotted owls of stands with different over- and under-story canopy coverage[a]

Canopy cover: Over-story	Canopy cover: Under-story	No. of observations	No. of acres	No. Obsns. per 100 acres
41-70%	41-70%	314	1568	20.0
0.40%	41-70%	88	1363	6.5
0-40%	0-40%	89	3191	2.8

[a]Data from Solis (1983).

Table B.13. Habitat selection by spotted owls in the Klamath and Six Rivers National Forests (source: Zabel et al. 1991).

		Klamath Nat'l Forest (Ukonum District)[a]		Six Rivers Nat'l Forest (Mad River District)[b]	
Variable	Value	% of Study area	% of Locations	% of Study area	% of Locations
Mean dbh	<5"	13	7	7	4
	5-10.9"	13	9	8	6
	11-20.9"	10	10	10	8
	21-35.9"	40	51	45	43
	>36"	24	23	31	39
Canopy cover	<10%	5	2	7	3
	10-19%	7	5	25	20
	20-39%	23	21	27	29
	40-69%	46	54	29	33
	70-100%	18	18	12	15

[a] Means based on 9 owls and 609 locations during the breeding season and 15 owls and 842 locations during the nonbreeding season.
[b] means based on 10 owls and 616 locations during the breeding season and 20 owls and 1,436 locations during the nonbreeding season.

bird varied considerably in canopy closure. The density of locations for one bird ("Bill") was higher in areas with higher canopy closure; one bird ("Luke") did not appear to discriminate on the basis of canopy cover; and the third bird ("Betsy") used thinned, and thus more open, stands more than unthinned, more closed stands. Kerns (1989) reported that brush rabbits comprised 33 percent of the prey (by biomass) of the owls he studied. (By contrast, this species comprised less than 1 percent of the biomass in the diet of the birds studied by Solis 1983.) Possibly, birds feeding heavily on brush rabbits do not show a strong preference for stands with dense canopies, but more data are needed to resolve this question.

A few studies have investigated preferences for other habitat features. Blakesley et al. (1992) found that roosting occurred more often at elevations of 1,000 to 3,000 feet than would be expected if sites were distributed randomly with respect to elevation. In contrast, Zabel et al. (1991) found that low elevations were preferred at both of the forests they studied during both seasons. Blakesley et al. (1992) found that owls avoided gentle slopes but other slopes were used in proportion to their availability. Zabel et al. (1991) found no preferences for slope. Blakesley et al. (1992) did not detect any preferences by owls for a particular aspect, and detected a preference for roosting on the lower third of slopes. Thus, in general, preferences for these features were either weak or inconsistent among sites.

Discussion

Recent results indicate that the pattern of habitat selection in California is more complex than that in Oregon and Washington north of the Klamath province and west of the Cascade crest. The 11 to 21-inch diameter category used in these stands corresponds roughly to the "young" category in Thomas et al. (1990). In the studies Thomas et al. (1990) reviewed, this size class was avoided by 55 percent of 130 birds and only preferred by 3 percent of them. Solis and Gutiérrez (1990) found similar patterns, but Blakesley et al. (1992) and Zabel et al. (1991) found little or no tendency to avoid this size class. The work of Sisco (1990) is particularly interesting. The birds he studied showed few preferences for habitat defined by mean diameter, but they selected sites for roosting and foraging that were similar to sites in old-growth stands.

The analyses employing canopy cover as well as tree diameter suggested that both of these variables may be important in determining preferred habitat in California. Results from the work of Solis (1983) summarized in Table B.12 suggested that both overstory and understory canopy cover were positively correlated with use by owls, as does the report by Zabel et al. (1991) in which owls generally preferred habitats meeting the Forest Service's definition of suitable habitat.

Additional use-availability analyses employing different habitat definitions, and functional studies of the specific resources provided by these habitats, should improve our ability to discern highly preferred and avoided habitats in California. Studies from the California Coast province, the California Cascades, and the eastside of the Cascades are also needed.

Abundance of Owls in Different Habitats

Thomas et al. (1990) concluded that in most parts of the range density was extremely low in landscapes dominated by stands less than 80 years old and lacking old-growth, and that density increased with the amount of old-growth present in a landscape or study plot. Thomas et al. (1990) also noted that recent studies in California "strongly suggest that suitable and even superior

spotted owl habitat can develop faster in coastal forest of redwood and mixed redwood and Douglas-fir" (p. 185) and that "the full range of suitable habitats for spotted owls in California has not yet been determined" (p. 166). Reports appearing since Thomas et al. (1990) are described in the following section.

Results

Carey et al. (1991) found spotted owls only in old-growth stands during a study in the southern Oregon Coast Range. Three owls were recorded in 1985, and six were recorded in 1986. The results showed a statistically significant tendency for abundance to increase with stand age, but sample sizes were inadequate to test the null hypothesis that abundance is equal in mature and old-growth stands.

Blakesley et al. (1992) found 79 nest sites in stands of 11 to 21 inches or more than 21 inches and no nests in other habitats. Nest densities per acre were virtually identical in the two habitats. Sites also were characterized by elevation, position, aspect, and slope. Elevations less than 1,000 feet were avoided and nests were concentrated in the lower third of slopes. No preferences were found for aspect or slope.

Meyer et al. (1992) reported that the amount of mature and old-growth forest in circles at owl sites was higher than the amount in randomly placed sites, a finding that is consistent with previous work. However, when individual successional stages were analyzed, only the amount of old-growth habitat was significantly greater at owl sites than at randomly placed sites.

We analyzed the data provided by Self and Brown (pers. comm.) to investigate relative densities of nests in different habitats. We defined the study area as all the land within 1.3 miles of the nests and recorded the amounts of different habitats in this area, and the number of nests per square mile of each habitat type. This type of analysis should not be used to estimate density of nests (or owls) in a given habitat across the entire landscape. For example, if a habitat were highly preferred for nesting and occurred only in scattered patches, then the process discussed previously would substantially underestimate true density. The analysis probably does provide a valid indication of relative preference, however, especially when substantial differences in density occur between habitats. In the data from Self and Brown (pers. comm.) nests were concentrated in the stands with the largest trees and densest canopy (Table B.14). Density was next highest in stands with smaller trees but dense canopies, and was lower in stands with more open canopies and either large or medium size trees. The study also suggested that montane forest types were not as preferred as Douglas-fir or mixed conifer types. Solis (1983:33, 41) also commented that the owls he studied seemed to avoid montane forest types.

Discussion

The suggestion by Thomas et al. (1990) that more work was needed on habitat suitability in California is supported by the recent results reported earlier. Findings by Blakesley et al. (1992) and Self and Brown (pers. comm.) that nests were almost equally common in stands with mean tree diameters of 11 to 21 inches and more than 21 inches provides a sharp contrast to results from Oregon and Washington. It is also noteworthy that in the study by Self and Brown (pers. comm.) density varied much more with canopy cover than it did with tree diameter (Table B.14). The structural features of nest sites in California (Table B.2) show a remarkable similarity to the structure of old-growth sites and nest sites elsewhere in the range. This suggests that owls in California are selecting sites with large trees even when the mean diameter in the

Table B.14. Habitat[a] within 1.3 miles of 21 northern spotted owl nests on managed lands in the eastern Klamath province (Self and Brown, pers. comm.).

Average Diameter	Canopy Cover	Area (mi^2)	Number of nests	Nests per mi^2
>24"	>60%	12.26	10	0.82
11-24"	>60%	4.94	3	0.61
>24"	40-60%	4.23	1	0.24
11-24"	40-60%	36.12	7	0.21

[a] Area covered by stands of Douglas-fir with an understory of tanoak and madrone or by stands of Klamath mixed conifers (white fir, Douglas-fir, ponderosa pine, incense cedar, and sugar pine with an understory of oak and maple).

stand is well below the mean in old-growth stands. This hypothesis should be investigated carefully because it has important implications for the design of strategies to protect owls in managed forestlands.

The combination of density (and demographic) data and structural features at the nest site and in the nest stand provides a powerful data set for analyzing habitat preferences. Similar information from other parts of California, and on the east side of the Cascades will be particularly useful in the future.

Demographic Rates in Different Habitats

Thomas et al. (1990) reported that proportion of territories with pairs and reproductive success declined as the amount of old-growth declined. This conclusion was based both on Forest Service monitoring data and on landscape studies. Results appearing since Thomas et al. (1990) are described in the next section.

Results

Meyer et al. (1992) did not find any consistent relationships between the number of years that sites were occupied by owls and various measures of forest fragmentation.

We reanalyzed the data from Meyer et al. (1992) to determine whether turnover of adults varied with the amount of older forest (i.e., more than 120 years) present in the circle. Persistence of adults was defined as the probability that a bird present in a circle at the start of a year would be found at the site the next year, given that the site was revisited in the following year. The consensus among spotted owl biologists is that adults rarely change breeding sites (Lint pers. comm., Franklin pers. comm., Gutiérrez pers. comm., Miller pers. comm., Wagner pers. comm.). For example, in the Andrews study area in the western Oregon Cascades, during 305 pair-years, divorce and settlement elsewhere occurred in, at most, four cases and was never established with certainty (Swindle and DeStefano pers. comm.). Persistence, as measured above, probably indicates adult survivorship, although we believe this issue needs further study. We obtained data from the 50 circles studied by Meyer et al. (1992), and Johnson (pers. comm.) supplied us with similar owl and habitat

data from 41 sites in the Andrews study area. We did not have individual identification on the birds from the Meyer et al. (1992) study so disappearances that were replaced before the start of the next season would not have been detected. We did have individual identification for the birds on the Andrews Forest and more accurate estimates of turnover rates.

We analyzed the two data sets separately and in combination. In all three analyses, persistence increased with habitat quality. The increase was significant in the BLM data set, not significant in the Andrews data set, and highly significant in the combined data set (Figure B.1, Table B.15). Neither the slopes nor the intercepts in the two data sets differed significantly (or close to significantly). In the combined data set, there was no evidence of nonlinearity. Heteroscedasticity (i.e., unequal variances) was evident but this causes no bias in the estimate of slope.

Simpson Timber Company (1991) reported that 0.72 young per pair were produced by 50 owl pairs in 1990 and that 0.63 young per pair were produced by 92 pairs in 1991; 68 percent of the new recruits in 1991 were adults, and; the turnover rate between 1990 and 1991 was 15 percent; three of 19 birds were found elsewhere and had moved rather than died. These values were similar to the values obtained nearby in the Willow Creek study area.

Discussion

The evidence suggesting that adult survivorship varies with amount of older forest in the home range is important because population viability is highly sensitive to adult survival rates. Obtaining more information of this sort should be a high priority for the future.

Results from Simpson Timber Company suggesting that rates of reproduction and adult survival are similar on Simpson's land and at Willow Creek are encouraging. The next few years should provide a good indication of how similar long-term reproduction and survival rates are at these two sites and provide a good basis for developing conservation programs on private land in this area. Identifying the key habitat features and analyzing whether they will remain present in the future should be a high priority in this study.

Table B.15. Regression analysis of occupancy data from the Andrews Experimental Forest and the BLM in Oregon.

Study	Number of Nests	Regression Equation (h = proportion of area covered by suitable habitat)	Standard Error of the Slope	Level of Significance
BLM	50	0.58 + 0.40h	0.18	~0.03
Andrews Experimental Forest	41	0.75 + 0.19h	0.18	~0.30
Combined data set	91	0.63 + 0.39h	0.12	~0.005

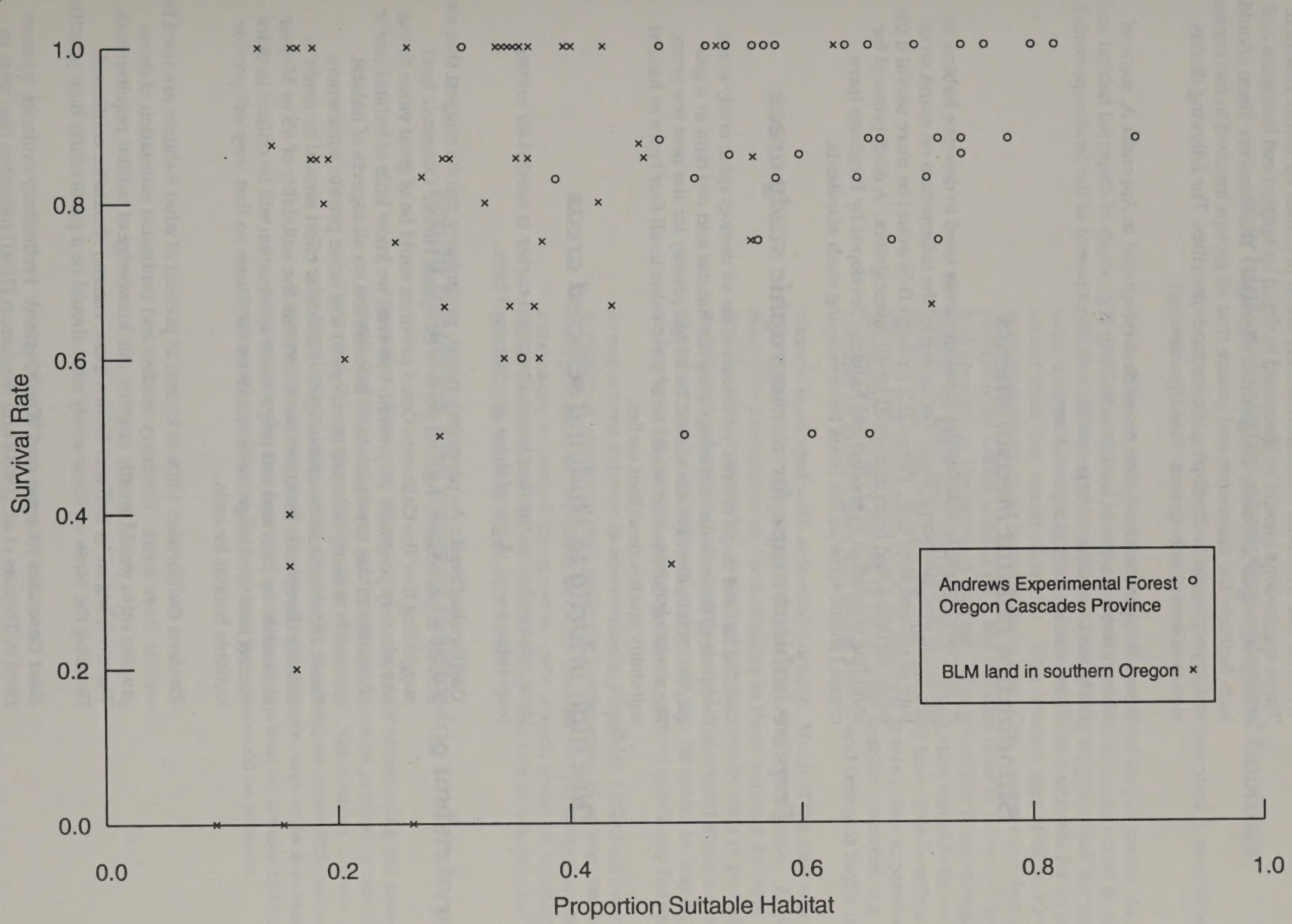

Figure B.1. Relationship between annual adult survival rates and proportion of the area within 1.3 miles of the activity center covered by older forest.

Recommendations for Future Research

We conclude with brief recommendations about priorities for future research. These suggestions should be discussed in detail by spotted owl biologists and the agencies that will carry out much of the work. The Recovery Team should help facilitate the discussion and ensure that all groups involved in owl conservation participate in developing the research priorities. The following discussion is intended to help meet that objective.

Several suggestions for future research are included in Appendix A, some of which involve studies of habitat suitability (e.g., study of dispersal habitat and the behavior of dispersing juveniles, and development of the landscape model). Those studies are not repeated here.

Standardize habitat measurements

A clear need exists to standardize measurements used to describe habitat at the stand and landscape level. For example, the information on stand structure at utilized sites (e.g., Tables B.2 through B.5) would be more useful if the same variables had been measured by all investigators. A draft protocol for sampling vegetation in spotted owl habitats developed by Bingham (pers. comm.) might serve as the basis for developing such standards.

Prepare habitat maps for demographic study areas

Detailed habitat maps are not yet available for all demographic study areas. Completing these maps and integrating the habitat and owl data in a geographic information system should be a high priority for the next few years. The resulting information would be of great value in all four types of habitat suitability studies described earlier.

Give high priority to studying selected areas

More information on the four issues described earlier is needed for certain geographic areas. A few of these are described here.

California Coast: As previously noted, preliminary results suggest that owl density is particularly high on parts of Simpson Timber Company land, suggesting that the California Coast province could be of great value in the owl recovery program. At present, however, we know little of habitat use or suitability in this province. More information on all aspects of habitat suitability is being collected by Simpson and other private landowners. These efforts should be encouraged. Particular effort should be made to identify the specific features that determine the suitability of 45 to 55-year-old stands for owls and owl prey. Such information will be critical in determining how to manage these stands in the future so that they will provide suitable habitat for owls.

Eastern California: Little is known at present of what habitats are used by owls in these areas. Telemetry studies and continued estimation of demographic rates would greatly improve our knowledge of habitat requirements. The work begun by Self and Brown (pers. comm.) should be continued. Banding the birds on these study sites should be a particularly high priority.

East Cascades (Oregon and Washington): Preliminary evidence summarized in Thomas et al. (1990) and Buchanan (1991) indicated that owls in some of this region are abundant and are using a wide variety of habitat

types. Work in Washington is continuing and should receive high priority. Use of habitat by radio-transmittered birds and adult turnover rates will be of particular interest.

Give high priority to studying selected habitats

More information on the four issues previously described is needed for certain habitats. A few of these are described here.

10 to 20-inch dbh plantations with remnant larger trees: As noted in Thomas et al. (1990), many sites are known where owls occur in young stands with remnant large trees. This finding suggests that leaving a few large trees at harvest might cause sites to become suitable for owls much sooner than they would otherwise. With rotation ages of 60 to 80 years, such sites might never be suitable for owls if no trees are left, but might provide some useful habitat for a few decades prior to harvest if large trees had been left at the previous harvest. This possibility is encouraging, but at present we know little of what makes existing sites valuable for owls. It is thus possible that leaving a few large trees will have little beneficial effect on owls, or that the benefits could be obtained in other, less expensive ways. Studies are therefore needed to identify the specific resources (e.g., owl prey) provided by existing sites with young stands and remnant larger trees.

Stands managed with selective harvest: Much of the east side forest and Klamath province is managed with selective harvest regimes. At present we have little information on the suitability of these habitats for owls. Telemetry studies are needed to determine relative use by owls of partially harvested and unharvested old-growth stands. Functional studies evaluating abundance and availability of prey would also be useful in helping us understand the current potential value to owls of selectively harvested sites.

Areas where salvage is economically feasible: Little information is available at present to help guide the development of policies on how much salvage should be permitted in DCAs or other owl protection areas. More information is needed about use by owls of such areas for foraging and about the effects of the harvestable snags and logs in accelerating return of the stand to suitable habitat for owls.

Study functions and ways of developing understory

Appendix G discusses silvicultural methods for accelerating the development of suitable habitat, and places particular emphasis on producing stands with the "reversed J" size-class distribution of trees (i.e., the number of trees decreases as the diameter increases). At present, however, we know little about why owls frequent stands with well-developed understories, and we lack detailed silvicultural studies showing how this understory can best be developed in different regions and conditions. Both of these issues should be studied.

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Appendix C

Demographic Analysis of Northern Spotted Owl Populations

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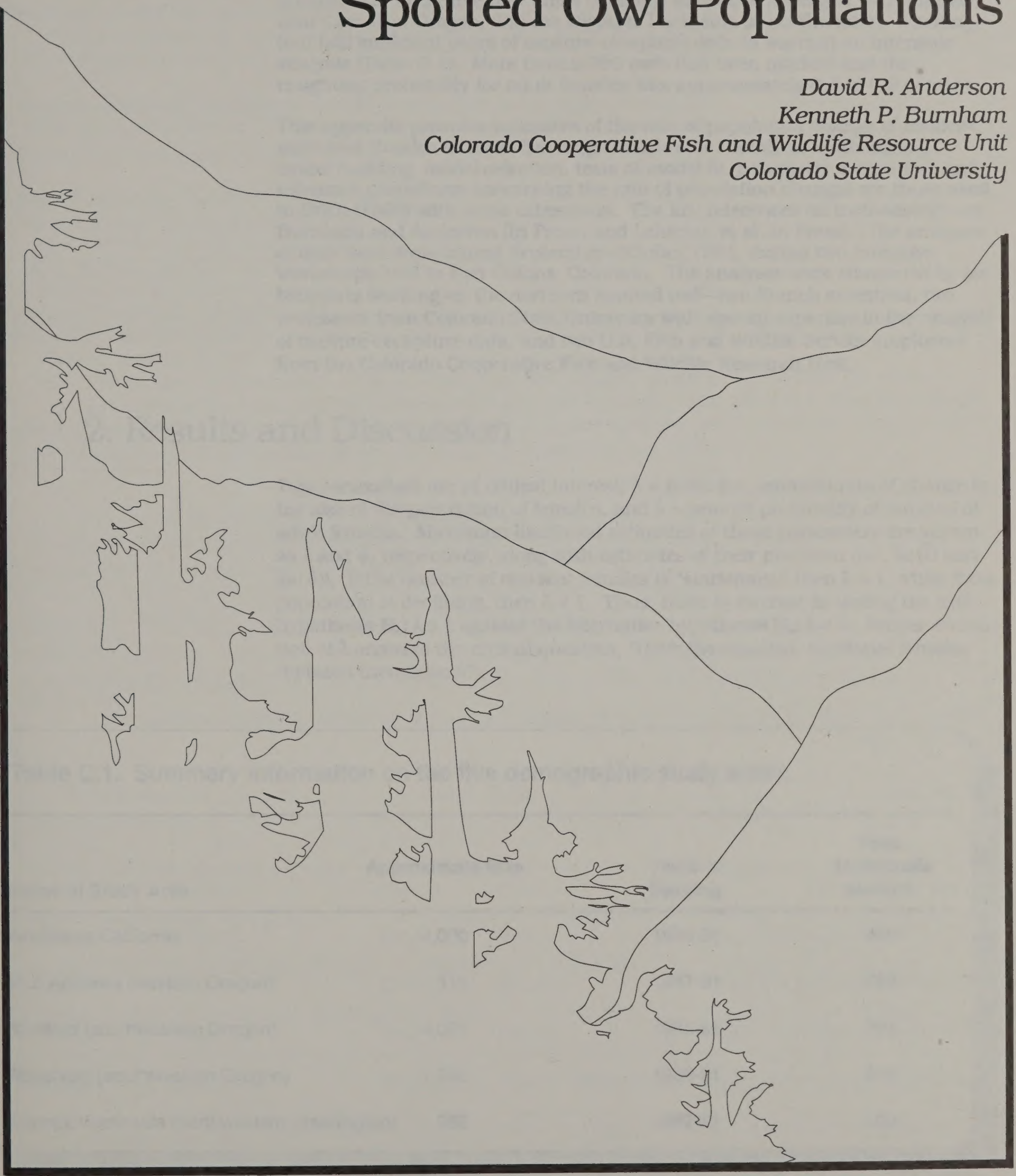

1. Introduction

The 1990 Status Review Northern Spotted Owl (USDI 1990) provided estimates of the rate of population change for populations of northern spotted owls in northern California (Willow Creek and surrounding regional study area) and southern Oregon (the Roseburg study area). The population of resident female owls in these areas was shown to be declining at a significant rate. By the fall of 1991, there were 2 additional years of capture-recapture data on these two populations, and three new areas (Medford in southern Oregon, H.J. Andrews near Corvallis, Oregon, and the Olympic Peninsula in northwestern Washington) had sufficient years of capture-recapture data to warrant an intensive analysis (Table C.1). More than 2,000 owls had been marked and the resighting probability for adult females was approximately 0.8 to 0.9 percent.

This appendix provides estimates of the rate of population change of resident, territorial females in these five large study areas. Analysis methods (e.g., model building, model selection, tests of model fit, parameter estimation, and inference procedures concerning the rate of population change) are those used in USDI (1990) with some extensions. The key references on methodology are Burnham and Anderson (In Press) and Lebreton et al. In Press). The analyses of data were done during September-October 1991, during two intensive workshops held in Fort Collins, Colorado. The analyses were completed by six biologists working on the northern spotted owl—two French scientists, two professors from Colorado State University with special expertise in the analysis of capture-recapture data, and two U.S. Fish and Wildlife Service employees from the Colorado Cooperative Fish and Wildlife Research Unit.

2. Results and Discussion

Two parameters are of critical interest; λ = finite (i.e., annual) rate of change in the size of the population of females, and ϕ = annual probability of survival of adult females. Maximum likelihood estimates of these parameters are shown as $\hat{\lambda}$ and $\hat{\phi}$, respectively, along with estimates of their precision (i.e., $\hat{se}(\hat{\lambda})$ and $\hat{se}(\hat{\phi})$). If the number of resident females is "stationary," then $\lambda = 1$, while if the population is declining, then $\lambda < 1$. Thus, there is interest in testing the null hypothesis $\mathbf{H_o}$: $\lambda \leq 1$ against the alternative hypothesis $\mathbf{H_a}$: $\lambda < 1$. Proper estimation of λ answers the critical question, "Have the resident, territorial females replaced themselves?"

Table C.1. Summary information on the five demographic study areas.

Name of Study Area	Approximate Size	Years of Marking	Total Individuals Marked
Northwest California	4,000	1985-91	400
H.J. Andrews (western Oregon)	116	1987-91	358
Medford (southwestern Oregon)	4,050	1985-91	703
Roseburg (southwestern Oregon)	1,700	1985-91	589
Olympic Peninsula (northwestern Washington)	965	1987-91	302

The estimation of λ was based on the Leslie-Lefkovitch approach summarized in USDI (1990). Under this method, estimates of age-specific survival and fecundity are needed for the female component of the population. Model selection for the estimation of survival probabilities relied on the Akaike Information Criterion (AIC), however some use of likelihood ratio tests was made. Data from the five study areas supported only two age-classes for annual survival estimates (juvenile and all older classes = "adults"). Estimates of these parameters and measures of their precision are presented in Table C.2.

Estimates of age-specific fecundity of females also followed the procedures in USDI (1990), and these are summarized in Table C.3. with a measure of the precision of the estimates.

Estimates of λ, computed from the estimates in Tables C.2. and C.3., estimated precision, and test statistics related to the null hypothesis (above) appear in Table C.4. While there are several potential biases in these estimates, it is clear from Table C.4. that the population of resident, territorial females has declined in each of the five study areas. The simple average of the estimates was $\hat{\lambda} = 0.9022$ which indicates a rate of decline of approximately 10 percent per year during 1985-1991. Thus, the resident population was not replacing itself in any of the five large study areas. This is a critical finding. In each case, $\hat{\lambda}$ is significantly less than 1 (see test statistics and P-values in Table C.4.). No statistical inference is made concerning λ prior to these years of study or in the future. These estimates of λ represent a 5- or 6-year "snapshot" of the average annual change in the female component of these five populations.

The t-test is based on the empirical variance among the five independent estimates of λ, while the z-test is based on the theoretical standard error of $\hat{\lambda}$ (i.e., $\sqrt{\Sigma\, \text{var}(\hat{\lambda}_i)\,/5}$). The t-test allows for significant variation in λ within the five study areas, however, a test for such variation was not significant (K^2=5.1409, 4 df, P=0.2731, (see Burnham et al. 1987:264-269). The estimated standard

Table C.2. Estimates of age-specific annual survival rates for female northern spotted owls.

Study Area	First Year		All Later Years	
	$\hat{\phi}_J$	$\hat{se}(\hat{\phi}_J)$	$\hat{\phi}_J$	$\hat{se}(\hat{\phi}_J)$
Northwest California	0.1946	0.0509	0.8507	0.0224
H.J. Andrews (western Oregon)	0.3112	0.1033	0.8365	0.0312
Medford (southwestern Oregon)	0.2002	0.0513	0.7854	0.0258
Roseburg (southwestern Oregon)[a]	0.2829	0.0366	0.8583	0.0131
Olympic Peninsula (northwestern Washington)[a]	0.0707	0.0282	0.8603	0.0264

[a] No sex-specific differences in adult survival were detectable, thus, the estimate of adult female survival includes adult males.

Table C.3. Estimates of age-specific fecundity (b) for female northern spotted owls (number of juvenile females/female of age x).

	Subadult 1 (12 mos.)		Subadult 2 (24 mos.)		Adult (36 mos.)	
Study Area	($\hat{b}_1$)	$\hat{se}(\hat{b}_1)$	($\hat{b}_2$)	$\hat{se}(\hat{b}_2)$	($\hat{b}$)	$\hat{se}(\hat{b})$
Northwest California	0.1154	0.0576	0.2286	0.0659	0.3576	0.0245
H.J. Andrews (western Oregon)	0.1430	0.0780	0.1430	0.0780	0.3270	0.0500
Medford (southwestern Oregon)	0.1110	0.0386	0.1110	0.0386	0.3233	0.4880
Roseburg (southwestern Oregon)[a]	0.0938	0.0547	0.0938	0.0547	0.3304	0.0385
Olympic Peninsula (northwestern Washington)[a]	0.1000	0.0667	0.1000	0.0667	0.3327	0.0784

[a] Year-specific differences in (b).
$\hat{b}$

error of the true $\hat{\lambda}$ across the five study areas ($\hat{\sigma}_\lambda$) was 0.0267 (95 percent confidence interval is 0.0 to 0.1073). Both tests indicate a strong rejection of the null hypothesis, and one must conclude that these populations are declining.

Capture-recapture methods allow estimates, of the number of new entries into the population of resident, territorial females (standard Jolly-Seber estimates, see USDI(1990:35-36)). Estimates of this quantity, averaged over years, are

Table C.4. Estimates of the finite rate of annual population change (λ) for female northern spotted owls in five independent study areas throughout their range. Also shown are test statistics and P values for the test of the null hypothesis that $\lambda > 1$ vs. $\lambda < 1$.

Study Area	$\hat{\lambda}$	$\hat{se}(\hat{\lambda})$	t or z	P
Northwest California	0.9153	0.0433	-1.9561	0.0252
H.J. Andrews (western Oregon)	0.9276	0.0437	-1.6567	0.0488
Medford (southwestern Oregon)	0.8444	0.0304	-5.1184	0.0000
Roseburg (southwestern Oregon)	0.9405	0.0182	-3.2692	0.0005
Olympic Peninsula (northwestern Washington)	0.8828	0.0280	-4.1857	0.0000
Simple average and t-test	0.9021	0.0173	-5/7532	0.0024
Simple average and z-test	0.9021	0.0153	-6.4155	0.0000

provided in Table C.5. Study of the results of these analyses indicated that statistically significant immigration had occurred each year in all five study areas. The estimates of the number of new entries (B^) provide insight into how populations in each area have been augmented by immigration from outside the study areas. These findings are consistent with those in the 1990 Status Review (USDI).

b. Meta-analysis

The majority of the capture-recapture data comes from adult birds (i.e., nonjuveniles) and therefore a sophisticated attempt was made to model and understand these data for each of the five study areas. Models of capture-recapture data must properly treat two types of parameters; conditional survival probabilities (ϕ) and conditional recapture probabilities (p) and how these vary across study areas (g). Age was not a factor in this analysis as only adults were treated, and sex was not a factor as only females were of particular interest. For theoretical reasons, much of the analysis was done on logit(ϕ) and logit(p), where, in general, $\text{logit}(\theta) = \log_e(\theta/(1-\theta))$. The parameters R and p might vary by year (t), and models were derived to allow for this effect. Time (t) in years was considered in two ways. First, the notation t denoted any significant variability in ϕ or p over years. Second, T was used to denote a linear trend in time in either logit(ϕ) or logit(p). Thus, a model allowing survival probabilities to vary across areas (g) and recapture probabilities to vary across years was denoted as (ϕ_g, P_T).

More complex models allowed several effects to be considered in a likelihood framework. An asterisk (*) denoted independent factors (e.g., g*t indicated that year-dependent parameters were incorporated in a model separately for each study area). Models employing a logit-linear structure were denoted by a "+" (e.g., g+t would indicate a model whereby study area was indexed by dummy variables, and parameters across time would be parallel on a logit scale) (see Hosmer and Lemeshow 1989). In all models, a log-likelihood ($\log_e(L)$) was used as the basis for statistical inference and estimation of model parameters was based on Maximum Likelihood methods. The model selection method (AIC) was objective; neighboring models were explored using likelihood ratio tests.

Table C.5. Estimates of the average annual number of new entries (B) into the adult population and the estimated average population size ($\hat{N}$) of northern spotted owls.[a]

Study Area	$\hat{B}$	$\widehat{se}(\hat{B})$	$\hat{N}$	$\widehat{se}(\hat{N})$
Northwest California	14.76	0.84	49.71	2.46
H.J. Andrews (western Oregon)	15.57	1.48	60.06	4.15
Medford (southwestern Oregon)	54.97	3.26	91.80	7.87
Roseburg (southwestern Oregon)	36.69	2.21	99.68	7.57
Olympic Peninsula (northwestern Washington)	24.44	1.06	51.20	3.56

[a] The estimates of $\hat{B}$ and $\hat{N}$ and measures of precision were made using program JOLLY (see Pollock et al. 1990).

Using the conventions above, either ϕ or p could be modelled in eight ways, g*t, g+t, t g*T, g+T, T, g or the null case, denoted -. Combinations of these eight structures for ϕ and p lead to 64 models of the five data sets on adult females. Table C.6. presents the number of model parameters, $-2 \cdot \log_e(L)$, and AIC for each of the models considered.

While the AIC-selected model was (ϕ_T, p_{g*T}), some neighboring models were tested to allow a deeper understanding of the data. These tests retain a very general model structure for the recapture probabilities. Three tests were of particular interest:

Test 1. $(\phi, p_{g*T}$ vs. (ϕ_t, p_{g*T}), $\chi^2 = 11.9666$, 5 df, P = 0.035.
Here, one concludes that there is significant year-specificity in adult female survival.

Test 2. (ϕ, p_{g*T}) vs. (ϕ_T, p_{g*T}), $\chi^2 = 4.930$, 1 df, P = 0.026.
Here, one concludes that there is a significant linear trend in logit(ϕ).

Test 3. (ϕ_T, p_{g*T}) vs. (ϕ_t, p_{g*T}), $\chi^2 = 7.036$, 4 df, P = 0.134.
Here, one concludes that there is no reason to use four additional parameters to let R vary by year, when a linear trend is satisfactory.

Finally, a Wald test (2-sided) of the significance of the slope in the relationship between logit(ϕ) vs. T is,

z = -2.287, P = 0.011. Thus, one concludes that the slope is significant.

This comprehensive analysis indicated a decreasing trend in annual adult female survival rate for the populations in the five study areas (Table C.7.). This finding is important because λ is critically influenced by the adult female survival (i.e., juvenile survival and fecundity are relatively less important in their influence on λ). Because the evidence strongly indicates that R decreased during the 1985-91 period, one must infer that λ also decreased over this period. That is, the rate of population decline was accelerating during the study period.

Biases in $\hat{\lambda}$

Estimates of juvenile survival have been contentious because estimates are biased low if some juveniles leave the study area, survive a full year, and never return to the study area. To the extent that these three events happen, juvenile survival is underestimated, and estimates of λ are too low (i.e., the true value of λ is probably larger than estimated).

Two approaches were employed to obtain more reasonable estimates of juvenile survival, ϕ_J. First, the maximum estimate of juvenile survival from the five study areas ($\phi_J = 0.311$, $\hat{se} = 0.103$) was used (cases 1 and 2 in Table C.8.). Second, data on juvenile survival from the best production year for the Medford and Roseburg areas were pooled to obtain a maximum estimate ($\phi_J = 0.3065$, $\hat{se} = 0.0764$) and this was used (cases 3 and 4, in Table C.8.). The Medford and Roseburg areas are large in size and adjacent to each other. Thus, the number of dispersing juveniles that survived and never returned is minimized in this approach. In each of the four cases, an attempt was made to use a realistic estimate of juvenile survival as one of the estimates affecting λ. Cases 1 and 3 allowed adult female survival to decline, while Cases 2 and 4 used an estimate of the average adult female survival from the pooled data. Table C.2. provides estimates of $\lambda = 1$. In each of the four cases, there was strong statistical evidence of a declining population.

Table C.6. Summary of statistics related to model selection, based on 64 models. For each model the three table entries are number of model parameters, -2·log$_e$(L), and AIC. The best model is indicated by the box.

Survival Rate ϕ	Recapture Rate, p: g*t	G+t	t	g*T	g+T	T	g	-
g*t	47 1664.54 1758.54	36 1681.92 1753.92	31 1700.07 1762.07	36 1674.01 1746.01	32 1683.27 1747.27	28 1701.75 1757.35	31 1686.76 1748.76	27 1705.23 1759.23
g+I	36 1672.76 1744.76	20 1694.44 1734.44	16 1713.53 1745.53	20 1689.23 1729.23	16 1698.32 1730.32	12 1715.82 1739.82	15 1703.48 1733.48	11 1719.62 1741.61
t	31 1673.82 1735.82	16 1702.36 1734.36	11 1721.30 1743.30	16 1691.92 1723.92	12 1705.49 1729.49	8 1722.69 1738.69	11 1708.83 1730.83	7 1725.85 1739.85
g*T	36 1674.09 1746.09	20 1696.88 1736.88	16 1714.06 1746.06	20 1690.32 1730.32	16 1698.65 1730.65	12 1717.14 1741.14	15 1701.63 1731.63	11 1720.15 1742.15
g+T	32 1677.43 1741.43	16 1705.04 1737.04	12 1719.75 1743.75	16 1696.17 1728.17	12 1706.46 1730.46	8 1723.24 1739.24	11 1710.89 1732.89	7 1726.14 1740.14
T	28 1678.54 1734.54	12 1711.22 1735.22	8 1725.85 1741.85	12 1698.96 1722.96	8 1714.22 1730.22	4 1730.82 1738.82	7 1716.35 1730.35	3 1732.83 1738.83
g	31 1678.39 1740.39	15 1708.71 1738.71	11 1721.44 1743.44	15 1701.81 1731.81	11 1714.77 1736.77	7 1729.76 1743.76	10 1715.12 1735.12	6 1729.90 1741.90
-	27 1679.11 1733.11	11 1712.14 1734.14	7 1726.42 1750.42	11 1703.89 1725.89	7 1719.31 1733.31	3 1735.57 1741.57	6 1719.33 1731.33	2 1735.60 1739.60

An additional perspective concerning this source of potential bias can be gained by examining the value for juvenile survival necessary to force $\lambda = 1$ (with the same adult survival and fecundity values). The large increases in estimated juvenile survival, shown here, seem unfounded.

Study	$\hat{\phi}_J \mid \lambda = 1$	% increase
Northwest California	0.49	151
H.J. Andrews	0.60	93
Medford	0.89	345
Roseburg	0.53	87
Olympic Peninsula	0.52	632
Average	0.61	190

In summary, even with optimistic assumptions about juvenile survival rates, the best information suggests that the population of resident, territorial owls has declined, on average, at an estimated rate of 7.5 percent each year during the 1985-91 period and that this rate of decline probably has accelerated in recent years.

Senescence is another potential problem; unaccounted for senescence leads to overestimation of λ. Likewise, it seems clear that fecundity is overestimated each year and this overestimation is more severe in years of poor production.

Table C.7. Estimates of average adult female survival (ϕ) during 1985-91 for the northern spotted owl, based on the best model out of 64 for the pooling of data across the five study areas.

Year	$\hat{\phi}$	$\hat{se}(\hat{\phi})$
1985-86	0.8880	0.0242
1986-87	0.8727	0.0202
1987-88	0.8556	0.0157
1988-89	0.8367	0.0124
1989-90	0.8158	0.0146
1990-91	0.7929	0.0231

Table C.8. Estimates of the finite rate of annual population change (λ) for the northern spotted owl obtained by pooling all the data across the five study areas. Cases (explained in the text) make differing assumptions about juvenile survival rates.

Case	Years	Female Survival Rate	$\hat{\phi}_J$	$\hat{\lambda}$	$\hat{se}(\hat{\lambda})$	z	P
1	1985-86	Declining	ϕ_{max1}[a]	0.9813	0.0373	-0.4879	0.3128
1	1990-91	Declining	ϕ_{max1}[a]	0.8857	0.0362	-3.1575	0.0008
2	1985-91	Constant	ϕ_{max1}	0.9259	0.0312	-2.3750	0.0088
3	1985-86	Declining	ϕ_{max2}[b]	0.9805	0.0322	-0.6056	0.2724
3	1990-91	Declining	ϕ_{max2}[b]	0.8844	0.0312	-3.7051	0.0001
4	1985-91	Constant	ϕ_{max2}	0.9246	0.0251	-3.0040	0.0013

[a] The survival rate of juveniles was used for the area with the highest survival rate.
[b] The year with the highest survival was used for the Medford and Roseburg areas, thus the emigration was lowest.

This source of bias in λ also tends to overestimate λ.

Sandland and Kirkwood (1981) noted that the recapture probabilities can be correlated and this leads to biases in the estimate of survival. This effect was tested, but no evidence of this effect was found. This effect is a minor problem when recapture probabilities are so high (i.e., 0.80-0.90).

3. Conclusions

Populations of resident, territorial females in all five large study areas have declined significantly, at an estimated average rate of 7.5 percent per year during the 1985-91 period. The parameter most important in λ is the annual survival rate of adult females and this parameter has decreased significantly during the 1985-91 period. Thus, the rate of population decline has probably accelerated.

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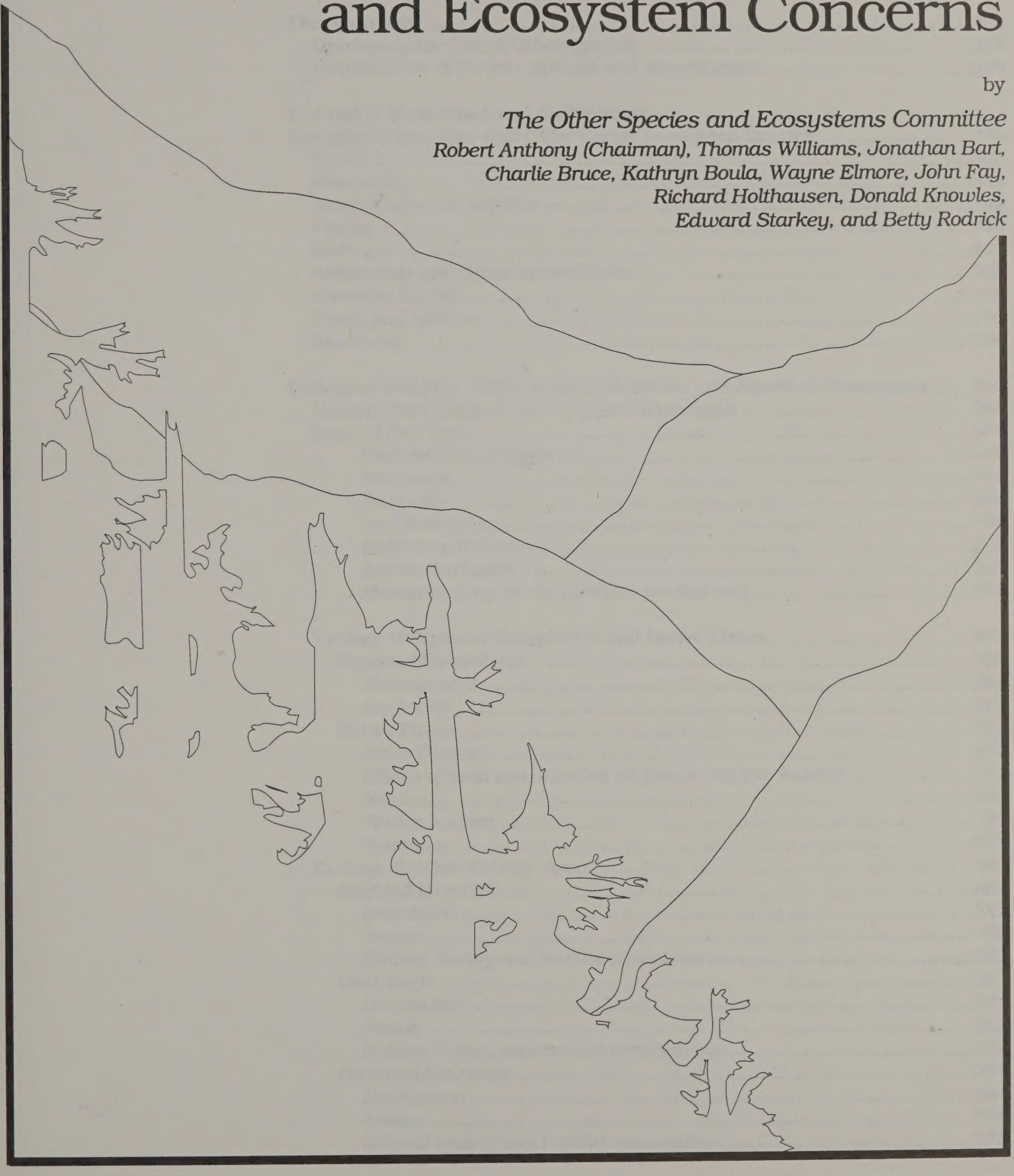
Appendix D

Consideration of Other Species and Ecosystem Concerns

by

The Other Species and Ecosystems Committee

Robert Anthony (Chairman), Thomas Williams, Jonathan Bart, Charlie Bruce, Kathryn Boula, Wayne Elmore, John Fay, Richard Holthausen, Donald Knowles, Edward Starkey, and Betty Rodrick



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Introduction

More than 450 species of birds, mammals, and amphibians occur in forests west of the crest of the Cascade Mountains in Oregon and Washington (Brown 1985:37), as well as 178 species of freshwater and anadromous fishes. The number of plant species in this area is also large and the number of invertebrate species is large, but cannot be determined accurately because many arthropods and molluscs have not been described and named (J. Lattin, Oregon State University; T. Frest, Deixis Consultants, pers. comm.). However, more than 3,400 species of arthropods have been reported from the H.J. Andrews Experimental Forest in the Oregon Cascade Mountains (Parsons et al. 1991). The Cascades region is about three times richer in mammalian species and about twice as rich in species of breeding birds as the coniferous forests of the coastal plains of the southeastern United States (Harris 1984:45). This high species richness reflects a great diversity of communities, ranging from estuarine to freshwater, from coastal to montane, and from prairie to temperate rain forest. Of the higher vertebrates (those other than fishes), about 58 percent are birds, 30 percent are mammals, 7 percent are amphibians, and 5 percent are reptiles (Harris 1984:47). In addition to the high species richness of mammals and birds, many unique faunal types are endemic to the Pacific Northwest. For example, the genus *Phenacomys* (*Arborimus*: tree voles) occurs only in western Oregon and northwestern California, and the region has more species of mammalian insectivores than any other part of temperate North America. Numerous species are narrowly or broadly endemic to western Oregon and Washington and northwestern California. The region also contains several unique species, such as the tailed frog, one of the most primitive extant amphibians, which has been essentially unchanged in the fossil record for millions of years. Although the amphibians are not as rich in species as the birds and mammals, most of the species are narrowly or broadly endemic to the Pacific Northwest (e.g., Oregon slender salamander, Siskiyou Mountain salamander) (Bury et al. 1991). In addition, there is evidence of a decline of amphibian populations in many parts of the world (Blaustein and Wake 1990). The number of amphibians that are associated closely with streams (Bury 1988) and the many dwindling fish stocks (Nehlsen et al. 1991) exemplify the importance of riparian ecosystems in coniferous forests.

The northern spotted owl is associated with older forest ecosystems in the Pacific Northwest (Forsman et al. 1984, Thomas et al. 1990), and optimal habitat for the species usually is found in old-growth forests that are more than 200 years old. Because of its association with older coniferous forests, the spotted owl has been used as an indicator species for older forest ecosystems. The owl is well-suited for this role in many respects because of its preference for mature or old-growth forests and its large home range size that varies from 1,000 to 10,000 acres from California to northern Washington (Thomas et al. 1990:194). The amount of mature and old-growth forest within a pair's home range also varies considerably from north to south (Thomas et al. 1990:195). The species' preferred habitat for nesting, roosting, and foraging throughout most of its range is old-growth coniferous forests. However, older forests are extremely diverse in structure and function, and it is clear that the owl can not represent all the key components of these forests.

Secretary of the Interior Lujan's charge to the Recovery Team included the following statement: "There are other forest ecosystem species that may be candidates for listing under the Endangered Species Act which may benefit from any recovery plan for the northern spotted owl. To the extent possible, the team should assess the relative benefits to these species from the implementation of various recovery options" (memo to the Recovery Team: February 5, 1991). As a result of this directive, a committee of the Recovery Team was

formed during the initial meeting to address this task. A working principle of the committee was that the recovery plan should take advantage of opportunities to benefit other species and ecosystem function. In the long term, a plan that adheres to this principle will be more sound ecologically and be a more efficient and cost-effective approach than a series of conservation measures aimed at single species.

Description of Older Forest Ecosystems

Coniferous forests in the Northwest succeed through three biological stages of development: young, mature, and old-growth. Precise definition of the latter stage is difficult because characteristics are influenced by a number of variables including species composition and climate. However, an interagency task group developed interim definitions for old-growth Douglas-fir and mixed conifer forests (USDA 1984). The task group suggested that the transition from mature forest to old-growth begins at about 175 or 200 years of age for Douglas-fir forests, with continuing change until these forests are much older. Specific characteristics vary with site but include: (a) two or more species of trees with a wide range of ages and sizes of large trees, usually Douglas-fir, with diameters 30 inches or ages older than 200 years; (b) multilayered canopy; (c) one to four conifer snags per acre with diameters greater than 20 inches and heights greater than 15 feet; and (d) 10 to 15 tons of down logs per acre with two to four per acre having diameters greater than 24 inches and lengths greater than 50 feet. The special significance of old-growth forests lies in the combination of characteristics they possess, rather than in any unique attribute. This was recognized explicitly in the interim definition of old-growth forests (USDA 1986) and the use of multiple criteria rather than single attributes to characterize these forests. Species composition and specific structural attributes vary with location. In northern California, mixed-conifer and mixed-evergreen forests contain Douglas-fir, white fir, sugar pine, and ponderosa pine in addition to deciduous species such as tanoak, Pacific madrone, and canyon live oak. In Oregon and Washington, Douglas-fir, western hemlock, Sitka spruce, and Pacific silver fir are common.

Throughout much of the region, total precipitation is high and the climate is moderate. Within old-growth stands, the climate is especially moderate, and many of the organisms that inhabit these forests cannot tolerate extreme heat or dryness. The combination of mild climate and year-round food supplies results in a high level of plant and animal diversity.

Historically, these forests did not extend across the landscape in an unbroken expanse of old-growth trees. Within the region there are mountainous areas that typically are dissected heavily by streams and rivers, as well as large expanses of less rugged terrain. Also, natural disturbances such as fire, wind, insect infestations, diseases, and volcanic eruptions created a mosaic of different-aged stands. This disturbance regime resulted in a patchy landscape and a diverse variety of habitats for animals. Natural disturbances differed significantly from clear-cut harvesting of timber. Intervals between fires west of the Cascades typically were much greater than those between harvests, and fires did not result in the relatively fine-grained fragmentation of habitats associated with clear-cut harvesting. The amount of coarse woody debris left afterward is the most significant difference between natural disturbance and logging. Far more wood is removed by harvesting than by fire, which may destroy only a few large trees and consume less than 20 percent of the coarse woody debris (Spies and Cline 1988).

Many attributes within these forests are important for wildlife. These forests are dominated by exceptionally long-lived conifer trees, and, in the absence of

disturbance, natural succession is a relatively slow process, especially during late seral stages. Thus, stable habitats are provided for species that cannot disperse readily from one suitable habitat to another. Large conifers also provide significant horizontal and vertical complexity. Individual trees have deep crowns, often with trunks and limbs that are deformed or scarred by wind, lightning, or mistletoe infection. Broken tree tops and irregular branches provide nesting habitat for many species. The understory of shade-tolerant trees, such as western hemlock, provide further vertical divesity. Openings develop in the canopy as a result of mortality of dominant trees. As the canopy opens, sunlight penetrates to the forest floor, and a diverse layer of shrubs and forbs develops, further increasing spatial complexity of the forest.

Perhaps one of the most important features of old-growth forests is the great quantity of dead wood they contain. Biomass of snags and down logs reaches 80 tons per acre in stands 500 years old (Spies and Cline 1988) with about one-third of this in snags and two-thirds in down logs (David Perry, Oregon State University, pers. comm.). Snags provide shelter and nest sites for a number of bird and mammal species. Harris and Maser (1984) suggest that elimination of snags in a mature, unmanaged Douglas-fir forest in the Cascade Mountains would reduce the number of resident wildlife species (not including bats) from 90 to about 80. Elimination of snags and logs would reduce the number to about 60. Snags are especially important to nonmigratory birds; Mannan (1977) found that about 60 percent of bird species in Douglas-fir forests during the winter were cavity-nesters.

Down logs are important features in terrestrial and aquatic habitats. Down logs contribute to structural diversity, provide hiding cover for small animals, and provide moist microhabitats during dry periods. Dead and decaying wood on the forest floor contain important water reserves that buffer the effects of the summer drought periods typical of the region (Perry 1991). Logs are also important elements of stream ecosystems. They provide baffles and dams that create pools and backwaters, increasing diversity of habitats within these systems. Logs and coarse woody debris also provide food for aquatic insects, which in turn provide food for predators at higher trophic levels. Fish biomass is related closely to quantity of coarse woody debris in Northwest streams (Harmon et al. 1986). Streams in managed forests typically contain few large logs.

There is not likely to be additional recruitment of extremely large diameter logs because rotation cycles are too short to permit the growth and mortality of extremely large trees.

Large numbers of terrestrial organisms also use coarse woody debris for food and shelter. Important examples include the northern flying squirrel and western red-backed vole. These important spotted owl prey species feed on mycorrhizal fungi, which appear to be associated with decaying logs (Maser et al. 1985, Ure and Maser 1982). Other vertebrates that use logs include salamanders, shrews, and marten (McComb 1991), as well as large numbers of invertebrates such as insects, slugs, and centipedes (Harmon et al. 1986, Parsons et al. 1991).

Older forests are productive and valuable as wildlife habitat although their value in this regard often has been underestimated. Isaac (1952) referred to old-growth as "biological deserts." Norse (1990) has suggested that this misperception was partly a result of preoccupation with game species, which tend to be less abundant in mature forests than in early seral environments.

Because of the complex combination of characteristics required, it is doubtful that managed forests with short rotations and even-aged management can

provide habitat for the numerous species associated with older forests. It is unlikely that a planted and even-aged, managed stand ever could simulate an old-growth system. However, habitat for many species can be provided in a managed environment; therefore, conservation efforts for many organisms associated with older forests, including the northern spotted owl, should include a combination of reserves and managed forests. Reserves would provide true old-growth environments for those species with very narrow ecological tolerance, and management practices for managed forests could be adapted to maintain populations of less specialized species that commonly are associated with older forests.

Northern Spotted Owl as an Indicator Species

Concern for northern spotted owls and debate over management of their habitat has been a persistent issue in Pacific Northwest forestry for two decades (USDA 1988, Thomas et al. 1990). However, spotted owls rarely have been the sole focus of this debate. Most frequently they have been used as a symbol of general concerns about the fate of old forests in the Pacific Northwest. The Forest Service recognized this general concern by designating northern spotted owls as a management indicator species (MIS) in the Forest Planning process (USDA 1984). Management for owls and other MIS was advanced as a way to adequately provide for the needs of several hundred other species associated with older forests (USDA 1988).

Biological indicators have been used successfully as gauges of environmental conditions in some situations (Thomas 1972). However, the use of vertebrate species as indicators for other vertebrates has proven unsuccessful in several studies (Mannan et al. 1984, Szaro 1986), and the concept has been questioned. The attempted uses of vertebrate indicators, and reasons for failure of the vertebrate indicator concept, were summarized by Landres et al. (1988). Vertebrates have been used as indicators of population trends and of habitat quality for other species. Their use as indicators of population trends for other species is likely to fail because each species responds to a different complex of habitat and climatic factors and is affected by interactions with other species. Mechanisms of population regulation also differ among species, making it even less likely that one could indicate the population trends of another. The use of vertebrates as indicators for habitat quality for other species is equally problematic. The factors that influence habitat quality are similar to those that influence population density. The probability is small that one species adequately can represent those factors for a number of other species.

Given the likelihood that no vertebrate can adequately represent a whole community of organisms, what are the potential hazards of establishing a management strategy based solely on habitat needs of spotted owls? First, at a landscape scale, the locations of conservation areas established to meet the needs of owls may not adequately provide for other species that have restricted ranges within the range of the spotted owl. Examples of this concern include the marbled murrelet, which occurs primarily in the coastal forests, and some amphibian and mollusc species that have extremely small ranges (see sections below). These species could be missed entirely by a system of reserves established for owls. Second, the spacing of conservation areas for owls may not accommodate movement of species that have much more limited dispersal capabilities. Amphibians, small mammals, and most invertebrates have limited ability to move among large established areas that are long distances apart. Finally, at the stand level, the specific habitat conditions that are maintained for owls may not provide habitat for other species. For example,

silvicultural practices in very young (less than 40 years) stands that are aimed at producing habitat structure for owls will not provide the branch structure associated with murrelet nest sites. Ruggiero et al. (1988) stated that as management becomes more tightly directed at a single species, it is less likely to provide for other species. Baker and Schonewald-Cox (1986) concluded that "Incorrectly assuming that other species are receiving protection as a result of the protection of [an indicator] can result in the inadvertent loss of those other species."

These cautions on the use of indicators were used in several ways in the development of the recovery plan. First, in developing the overall strategy for spotted owl recovery, the Recovery Team evaluated the overlap between possible spotted owl management areas and the ranges and locations of other species that were judged to be priorities. Second, in developing recommendations for management practices of DCAs, the Recovery Team attempted to look beyond the habitat attributes associated with spotted owls. Wherever possible, the Recovery Team used the structure and functioning of older forests as a benchmark for recommendations on management activities. This insured that those activities would help provide habitat for other species and not focus so specifically on spotted owls that other species were inadvertently harmed.

Riparian Ecosystems

Riparian areas are among the most ecologically important components of forest landscapes. There are several definitions for riparian areas, but basically they are areas where soils contain free or unbound water and are recognized by unique vegetation types adjacent to lakes, streams, rivers, ponds, marshes, seeps, or bogs. They form boundaries between different ecosystems and provide connectivity for interchange and dispersal for plants and animals.

Spotted owls often are associated with riparian areas within their home ranges. Forsman (1976) first noted this relationship; he reported that all but three nests he located were within 425 yards of water. Later, Forsman et al. (1984) noted the same relationship for a larger sample of nest sites. Using radio-telemetry, Solis (1983) and Solis and Gutierrez (1990) also reported that roosting and foraging sites were more likely to be found on the lower thirds of slopes (i.e., near streams within their home ranges) than elsewhere. Finally, Blakesley et al. (In press) report a similar relationship in northwestern California. Their study analyzed all roost and nest sites used by an entire population of owls over a 5-year period. Thus, analysis of individual selection and population selection have noted an association of spotted owls with riparian areas.

The association of spotted owls with streams and associated vegetation is not well understood, but there may be several reasons for the observed relationship: 1) riparian areas usually are cooler, which may facilitate thermoregulation in the owls (Barrows and Barrows 1978; Barrows 1981); 2) riparian areas in the Pacific Northwest often are more productive areas in terms of tree growth, and this may promote more rapid development of suitable nest sites; 3) riparian areas usually support a more diverse biota than adjacent areas, resulting in the structural diversity that is characteristic of spotted owl habitat; and 4) riparian systems are more floristically rich and consequently may support higher numbers and abundance of prey species.

The Approach

A committee of the Recovery Team was formed to address concerns for other species and older forest ecosystems. The committee was composed of the following Recovery Team members and staff:

Robert Anthony (Chairman)—U.S. Fish and Wildlife Service
Jonathan Bart—U.S. Fish and Wildlife Service
Charlie Bruce—Oregon Department of Fish and Wildlife
Wayne Elmore—U.S. Bureau of Land Management
John Fay—U.S. Fish and Wildlife Service
Richard Holthausen—U.S. Forest Service
Donald Knowles—U.S. Department of Interior
Edward Starkey—National Park Service

Later in the process, Kathryn Boula, Thomas Williams, Betty Rodrick, and Rosemary Stussy were hired to help with various aspects of the information gathering and writing of this section of the recovery plan. The group also contracted responsibilities for parts of the biota to outside scientists, including the Washington Department of Wildlife (marbled murrelets); Joseph Beatty, Oregon State University (salamanders); Andrew Blaustein, Oregon State University (toads and frogs); Terrence Frest, Deixis Consultants (molluscs); Jack Lattin, Oregon State University (invertebrates); Andrew Moldenke, Oregon State University (invertebrates); Daniel Rosenburg, Redwood Sciences Lab (spotted owl prey); and Robert Storm, Oregon State University (salamanders).

Developing the List of Other Species

The committee's first decision was to consider all components of the biota associated with older forests and spotted owl habitat. However, the scope of this effort later was focused on species that were listed federally as threatened or endangered, candidates for federal or state listing, state sensitive and species of special concern. We also included species that have been shown to be associated with older coniferous forests within the range of the owl. The general approach consisted of the following:

1) Delineate the area of focus (i.e., the range of the northern spotted owl).

2) Compile a list of threatened and endangered, candidate, sensitive, and older-forest associated species.

3) Develop a short list of priority species by determining which species:
    a) occur within the range of the northern spotted owl
    b) are more abundant in older forests
    c) are in most need of conservation measures

4) Acquire definitions and maps of important habitat for the list of priority species.

5) Develop a geographic information system (GIS) mapping scheme to overlay important areas of habitat for the priority species with potential conservation areas for the spotted owl.

6) Identify areas of high species richness.

The list of species was developed in a series of meetings with more than 60 biologists, other scientists, and managers from the Pacific Northwest who had a wide array of expertise. The committee also reviewed lists of threatened and endangered, candidate, and sensitive species from the U.S. Fish and Wildlife Service, Washington Department of Wildlife, Oregon Department of Fish and Wildlife, and California Department of Fish and Game. To identify species associated with older forests, the committee reviewed the results of the Forest Service's Old-Growth Wildlife Habitat Research Program (Ruggiero et al. 1991a). A series of meetings on other species and ecosystem concerns was conducted by members of the committee from May through August 1991. The committee met seven times, and members of the committee conducted more than 25 meetings with outside biologists, other scientists, and managers in the three states. Records of the committee's consultation with other individuals are included in the administrative record of the recovery plan.

Identification of Priority Species and Assemblages

The short list of priority species represents a consensus of the committee members. Highest priorities were assigned to threatened or endangered species or those that are candidates for listing in at least parts of their geographic range. Attention also was given to species that have restricted geographic ranges or are endemic to the Pacific Northwest; species that have been designated as management indicator species of older forests by the Forest Service (i.e., pileated woodpecker, goshawk, fisher, marten); and spotted owl prey species (woodrats, flying squirrel, red tree vole, red-backed vole).

In developing the list of species, it became apparent that riparian ecosystems in older coniferous forests were of particular importance and concern. The importance of these ecosystems is demonstrated by the numerous species and stocks of native fishes, amphibians, molluscs, aquatic insects, small mammals, and birds that are associated with them. In addition, spotted owls often are associated with riparian areas.

A short list of priority species was developed and concerns related to riparian ecosystems were identified. Committee members reviewed numerous publications, geographic ranges, status of populations, natural history, habitat associations, and factors affecting populations and habitat. In addition, the committee sponsored a 2-day workshop on priority species and riparian ecosystems to which scientists were invited to present information on priority species. The workshop included opportunities for questions and answers at the end of each presentation. In all, 16 speakers presented information on the marbled murrelet, goshawk, bald eagle, marten, fisher, riparian ecology, native fish, amphibians, spotted owl prey, vascular plants, fungi, and ecological corridors. The entire workshop was transcribed by a court reporter for the committee. Initially, there was a manual mapping exercise that designated land ownerships, habitat conservation areas for the owl from the Interagency Scientific Committee (Thomas et al. 1990), critical habitat areas as proposed by the U.S. Fish and Wildlife Service, and significant old-growth areas as designated by a congressional scientific panel (Johnson et al. 1991). Later, this effort was incorporated into a GIS mapping procedure that allowed more efficient evaluation of options (see Appendix I for a description of GIS mapping methods).

The List of Threatened and Endangered, Candidate, Sensitive, and Older Forest Associated Species

The list of species considered in the recovery plan for the northern spotted owl includes 23 birds, 18 mammals, 23 amphibians, 28 fish, 58 molluscs, 59 arthropods, and 152 plants. Of these species, five (bald eagle, gray wolf, grizzly bear, Sacramento River winter chinook salmon, McDonald's rock cress) are federally listed as threatened or endangered, and the marbled murrelet and several fish stocks are proposed for federal listing. More recently, the northern goshawk has been petitioned for listing throughout the western United States. More than 100 species are listed or designated as sensitive species or species of special concern in one or more of the three states and could become candidates for federal listing in the future. Of the above, approximately 200 species of birds, mammals, amphibians, and plants are associated with or closely associated with older (more than 80 years) forests (Ruggiero et al. 1991b). "Closely associated" species are those whose abundance was statistically significantly greater in one forest seral stage than another. Species "associated with" a forest class are those found to be numerically more abundant in one seral stage than another, but differences were not statistically significant. Although many species were detected in older Douglas-fir forests in the study, the list includes only those species for which significant statistical or ecological correlations with older Douglas-fir forests were detected. Additional species occur in older forests that were not detected by Ruggerio et al. (1991b). These species include the bald eagle, which uses older forests for nesting and communal roosting (Anthony et al. 1982), and the goshawk on the Olympic Peninsula in Washington (D. Hayes, Washington Department of Wildlife, Olympia, Washington, pers. comm.) and northwestern California (Hall 1984). The list of species associated with older forests is useful in determining the number and variety of species that might become candidates for listing as threatened or endangered if older forests are converted to short-rotation, even-aged forests.

Birds

Twenty-three species of birds are included on the list for consideration in the recovery plan (Table D.1). One species, the bald eagle, currently is listed federally as threatened in Oregon and Washington and endangered in California. The marbled murrelet has been proposed for federal listing as threatened in all three states, and there has been a petition for listing the goshawk throughout the western United States. The pileated woodpecker and the white-headed woodpecker are management indicator species for the Forest Service because of their strong association with older forests on the west and east sides of the Cascade Mountains, respectively. The Vaux's swift, white-headed woodpecker, and chestnut-backed chickadee are broadly endemic to the Pacific Northwest, and 20 of the 23 species are associated with or strongly associated with older forests in one or more of the three states (Ruggiero et al. 1991). The marbled murrelet is of particular concern to the Recovery Team because of its strong association with older forests for nesting and the recent proposal to list the species in Oregon, Washington, and California. Further, its use of older forests for nesting is unique; marbled murrelets use large moss-covered limbs for nest construction, and these structures are found only on the

Table D.1. A list of threatened and endangered, sensitive, candidate, and old-growth associated birds within the range of the northern spotted owl.

	Status[a,b]				Old Forest Association[c]			Endemic[d]		Priority	Riparian	
		State										
Species	Fed	WA	OR	CA	WA	OR	CA	L	B	Species	Associate	References[e]
Marbled murrelet *Brachyramphus marmoratus*	PrT	C	SC	E	*	*	*			X		5,9,12
Northern goshawk *Accipiter gentilis*	Pet	C	SC	SC	+	+	+			X		8,11
Bald eagle *Haliaeetus leucocephalus*	E	T	T	E	*	*	*			X	X	1,2
Vaux's swift *Chaetura vauxi*		C			*	*	?		X			12
Harlequin duck *Histrionicus histrionicus*		G	SR	SC							X	
Pileated woodpecker *Dryocopus pileatus*		C	SC		+	+	+					4,12
White-headed woodpecker *Picoides albolarvatus*		C	SC		+	+			X			3
Black-backed woodpecker *Picoides articus*		M	SC		+	+						7
Red-breasted sapsucker *Sphyrapicus ruber*					+	+	*					10,12
Western flycatcher *Empidonax difficilis*					+	+	*					10,12
Hammond's flycatcher *Empidonax hammondii*							*		X			13
Chestnut-backed chickadee *Parus rufescens*					+	+	+		X			10,12
Brown creeper *Certhia americana*					+	+	*					12
Winter wren *Troglodytes troglodytes*					+	+	+					10,12
Red-breasted nuthatch *Sitta canadensis*					+	+						12
Hermit warbler *Dendroica occidentalis*							*					10,12
Wilson warbler *Wilsonia pusilla*					+		+					10,12
Warbling vireo *Vireo gilvus*							+					10
Hermit thrush *Catharus guttatus*							*					10
Flammulated owl *Otus flammeolus*		C	SC		+	+	+					6
Willow flycatcher *Empidonax traillii*				E							X	
Northern pygmy owl *Glaucidium gnoma*			SU			+	?					12
Great gray owl *Strix nebulosa*		M	SV	E								

WA = Washington OR = Oregon CA = California

[a]***Federal status:*** E = endangered, T = threatened, C = candidate, PrT = proposed threatened, Pet = petition pending.

[b]***State status:*** WA, C = candidate, M = monitor, X = extirpated, G = game. **OR**, SC = sensitive (critical), SV = sensitive (vulnerable), SR = sensitive (rare), SU = sensitive (undetermined), X = extirpated. **CA**, SCT = state candidate for listing as threatened, SC = species of concern, E = endangered. Sources (state): California Department of Fish and Game (1991a). Oregon Department of Fish and Wildlife (1991). Washington Department of Wildlife (1991a and 1991b)

[c]+ = old-growth associated, * = close old-growth associated, ? = species not studied or data insufficient (Ruggiero et al. 1991).

[d]***Endemic:*** L = local, B = broadly (see Ruggiero et al. (1991) for definition and list of endemic species).

[e]***References:*** 1) Anthony et al. 1982. 2) Anthony and Isaacs 1989. 3) Bull 1990 and 4) Bull 1991, USDA Forest Service, LaGrande, Oregon, pers. comm. 5) Cummins 1991. 6) Goggans 1986. 7) Goggans et al. 1987. 8) Hayward et al. 1990. 9) Nelson 1990. 10) Raphael 1985. 11) Reynolds et al. 1982. 12) Ruggiero et al. 1991. 13) Sakai and Noon 1991.

oldest trees in a stand. Eight of the species on the list belong to a group of birds, the cavity-nesters (pileated woodpecker, white-headed woodpecker, black-backed woodpecker, red-breasted sapsucker, chestnut-backed chickadee, winter wren, red-breasted nuthatch, and flammulated owl), that require snags for nesting and/or foraging. Optimal habitat for these species is found in old-growth forests, where the abundance of large snags is greatest (Nelson 1989, Mannan et al. 1980). Of the 23 species of birds, only three (marbled murrelet, bald eagle, goshawk) were chosen as priority species. The committee concluded that the remainder of the species would benefit from a recovery plan that includes mature and old-growth forests, and they did not require any special attention.

Mammals

Eighteen species of mammals are included on the list for consideration in the recovery plan (Table D.2). Two species, the gray wolf and grizzly bear, currently are listed federally as endangered, and the western big-eared bat is a candidate for state listing in Washington and Oregon. The marten is a management indicator species for the Forest Service because of its association with older forests. The red tree voles, white-footed vole, western red-backed vole, and shrew mole are endemic to the Pacific Northwest (Figures D.1 and D.2). Twelve of the eighteen species are associated with or strongly associated with older forests in one or more of the three states, and two of these species are bats for which there is very little information. Five species are associated with riparian areas. Six species belong to a group that are prey of the northern spotted owl, including the northern flying squirrel, red tree voles, western red-backed vole, dusky-footed woodrat, and bushy-tailed woodrat (Thomas et al. 1990, Figure D.2). As a group, they represent the major prey species of the owl other than the deer mouse and snowshoe hare (Forsman et al. 1984, Thomas et al. 1990). The red tree voles, red-backed vole, and northern flying squirrel are associated with older forests throughout most of their range in this region (Carey 1989), with the exception of the flying squirrel in the Oregon Cascades, where Rosenberg and Anthony (1992) found similar densities in old- and second-growth forests. Of the 18 species, nine were chosen as priority species that would be most likely to benefit from measures taken to recover the owl. However, six of these species are prey of the northern spotted owl and were chosen solely for that reason. The only species considered likely to benefit from specific measures included in the recovery plan were the marten, fisher, gray wolf, and grizzly bear, and the last two occur only in northern Washington. It was assumed that the remainder of the species would benefit from any recovery plan that conserves older forest as suitable habitat for owls.

Amphibians and Reptiles

Twenty-six species of amphibians and reptiles are included on the list for consideration in the recovery plan, including eight salamanders, six toads and frogs, one snake, and one turtle (Table D.3). None of the species is listed federally as threatened or endangered, but the western spotted frog has been petitioned for listing and four species of salamanders in the genus *Plethodon* are candidates for listing. Twelve of the species are associated with riparian areas directly and 12 with older forests. All but three of the species are designated as "species of special concern" in one or more of the three states. Most of the amphibians are endemic to the Pacific Northwest (Beatty et al. 1991), and some of the species (e.g., Oregon slender, Larch Mountain, Siskiyou Mountain, and Van Dyke's salamanders) have very restricted distributions (Figures D.3 - D.5). Most of the species have specific habitat requirements;

Table D.2. A list of threatened and endangered, sensitive, candidate, and old-growth associated mammals within the range of the northern spotted owl.

Species	Status[a,b] Fed	State WA	State OR	State CA	Old Forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority species	Riparian associate	References[e]
Marten *Martes americana*		G	S	S	+	+	+			X	X	3
Fisher *Martes pennanti*	C2	S	S	SC	+	+	+			X		5
Gray wolf *Canis lupis*	E	E	X	X						X		
Grizzly bear *Ursus arctos*	E	E	X	X						X		
Dusky-footed woodrat *Neotoma fuscipes*				SC			+		X	X	X	4
Bushy-tailed woodrat *Neotoma cinerea*									X	X	X	
Northern flying squirrel *Glaucomys sabrinus*				SC	?	+	?			X		5
Red tree vole *Phenacomys longicaudus*						*		X		X		2,5
Red tree vole *Phenacomys pomo*				SC			+	X		X		2,5
White-footed vole *Phenacomys albipes*			SR	SC				X			X	1
Western red-backed vole *Clethrionomys californicus*							+	X		X		4,5
Forest deer mouse *Peromyscus oreas*					+			X		X		5
Silver-haired bat *Lasionycteris noctivagans*					+	*	?					5
Western big-eared bat *Plecotus townsendii*		C	SC	SC								
Long-legged myotis *Myotis volans*		M			*	*	?					5
Shrew mole *Neurotrichus gibbsii*					+	+	?	X				5
Woverine *Gulo gulo*	C2	M	T	T								
Fringed myotis *Myotis thysanodes*		M	SV		?	*	?					5

WA = Washington **OR** = Oregon **CA** = California

[a]***Federal status:*** E = endangered, T = threatened, C = candidate, C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act, PrT = proposed threatened, Pet = petition pending.

[b]***State status:*** WA: C = candidate, M = monitor, X = extirpated, S = sensitive, G = game; **OR**: S = sensitive, SC = sensitive (critical), SV = sensitive (vulnerable), SR = sensitive (rare), SU = sensitive (undetermined), X = extirpated; **CA**: S = sensitive, SCT = state candidate for listing as threatened, SC = species of concern, E = endangered.

California Department of Fish and Game. 1991a. Oregon Department of Fish and Wildlife 1991. Washington Department of Wildlife (1991a and 1991b).

[c]+ = old-growth associated, * = close old-growth associated, ? = species not studied or data insufficient (see Ruggiero et al. 1991).

[d]***Endemic:*** L = local, B = broadly (see Ruggiero et al. (1991) for definition and list of endemic species).

[e]***References:*** 1) Gomez 1992. 2) Johnson and George 1991. 3) Marshall 1991. 4) Raphael 1985. 5) Ruggiero et al. 1991.

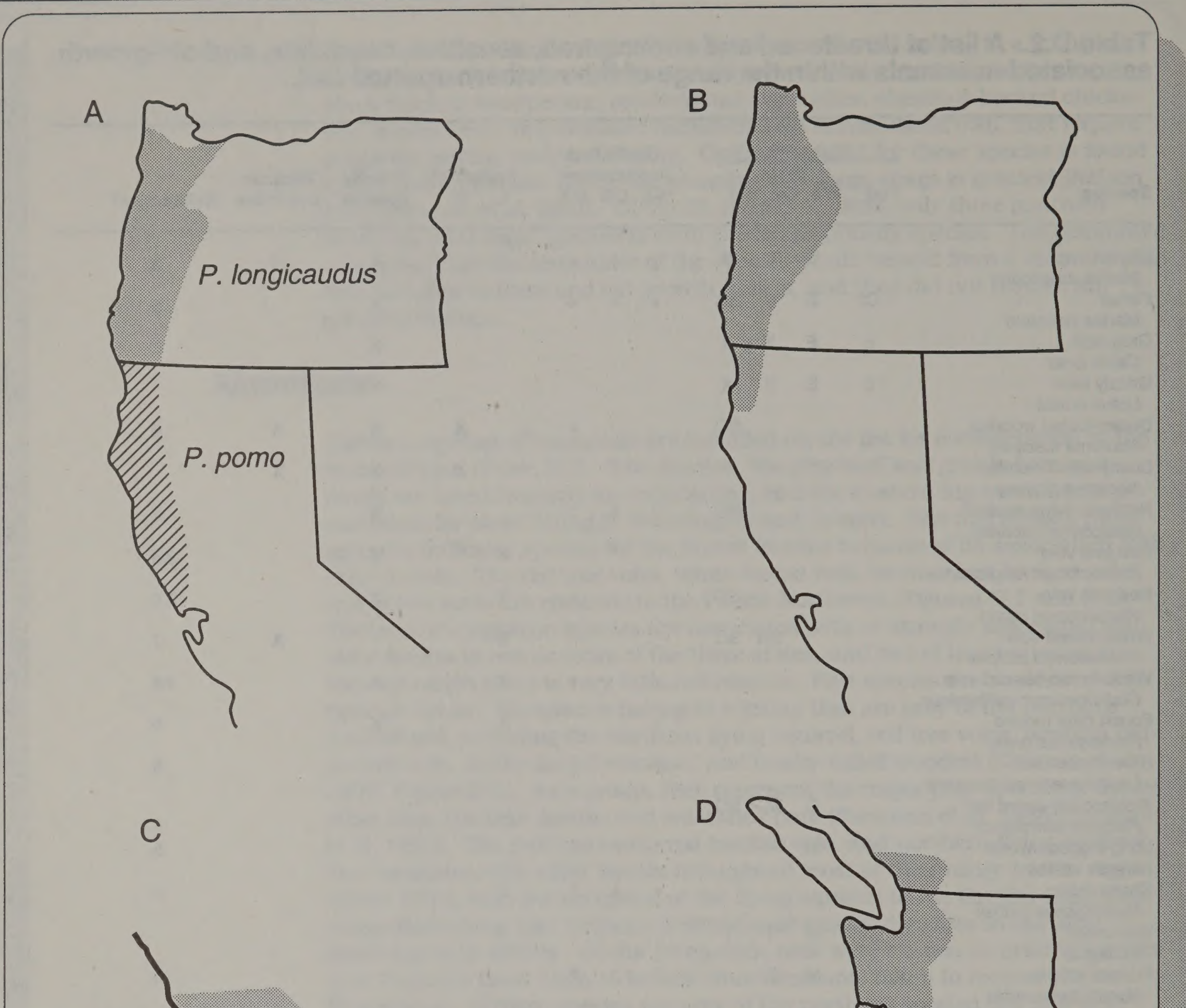

Figure D.1. *Distribution of: a) red tree voles (Phenacomys longicaudus, P. pomo), b) white-footed vole (P. albipes), c) forest deer mouse (Peromyscus oreas), and d) shrew mole (Neurotrichus gibbsii).*

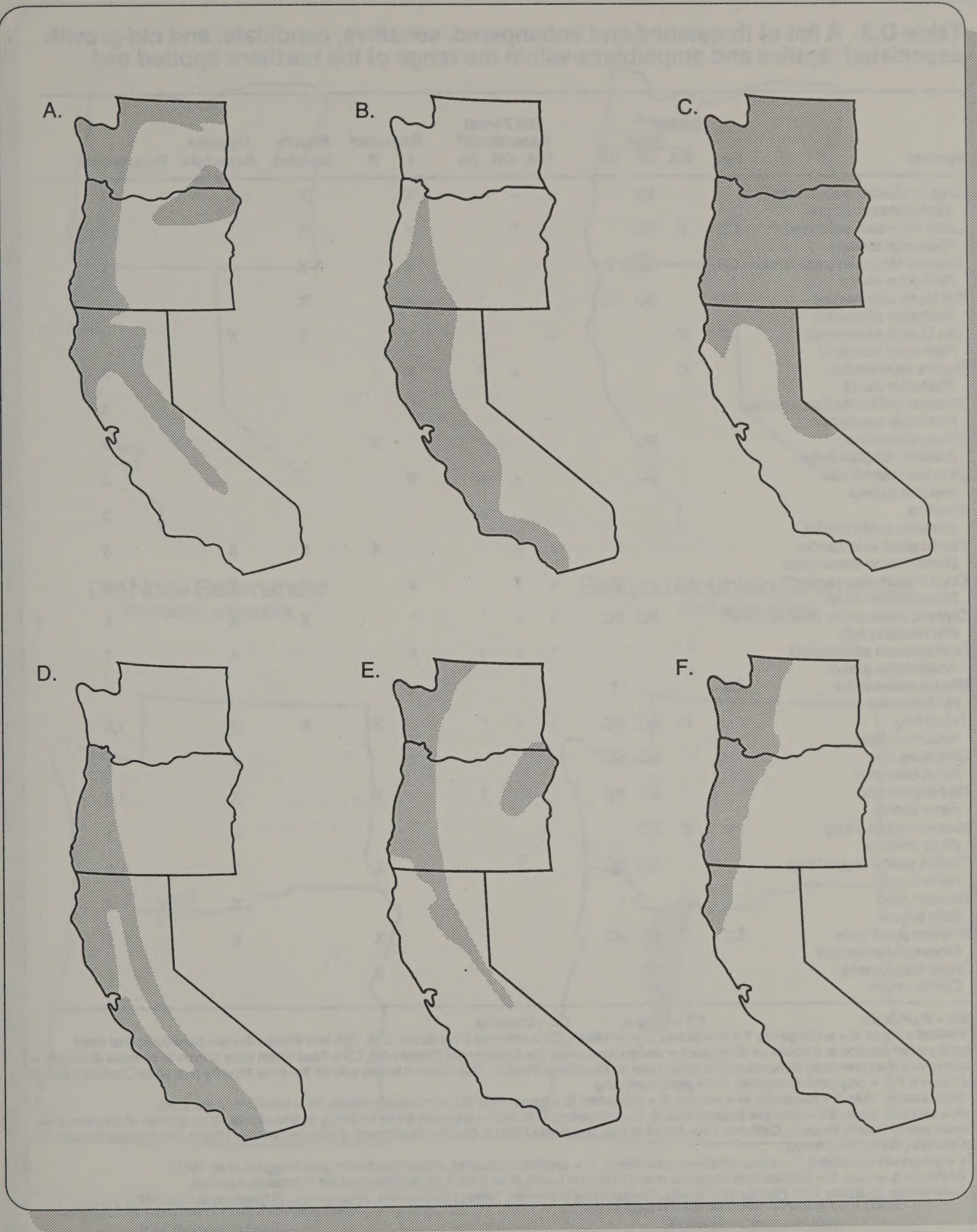

Figure D.2. *Distribution within Washington, Oregon, and California of the major prey species of the northern spotted owl: a) northern flying squirrel, b) dusky-footed woodrat, c) bushy-tailed woodrat, d) brush rabbit, e) snow-shoe hare, f) western red-backed vole. Adapted from Ingles (1976), with the permission of the publishers. Stanford University Press. Copyright 1947, 1954, and 1965 by the Board of Trustees of the Leland Stanford Junior University.*

Table D.3. A list of threatened and endangered, sensitive, candidate, and old-growth associated reptiles and amphibians within the range of the northern spotted owl.

Species	Status[a,b] Fed	State WA	State OR	State CA	Old Forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority Species	Riparian Associate	References[e]	
Oregon slender salamander *Batrachoseps wrighti*			SC			+		X		X		1,3	
Larch Mountain salamander *Plethodon larselli*	C2	C	SC			*		X		X		1	
Siskiyou Mountain salamander *Plethodon stormi*	C2		SC	T				X		X		1	
Del Norte salamander *Plethodon elongatus*	C2		SC	SC			*	X		X		1,3	
Van Dyke's salamander *Plethodon vandykei*	C3	C			+			X		X	X	2	
Dunn's salamander *Plethodon dunni*		C				+	?	X				3	
Western red-backed salamander *Plethodon vehiculum*								X				3	
Black salamander *Aneides flavipunctatus*			SC						X			3	
Clouded salamander *Aneides ferreus*			SC			+	+	X				3	
Ensatina *Ensatina eschscholtzii*							+					3	
Pacific giant salamander *Dicamptodon tenebrosus*					+	+			X	X	X	3	
Cope's giant salamander *Dicamptodon copei*					+	?		X		X	X	3	
Olympic salamander (four species) *Rhyacotriton* spp.			SC	SC	+	+	*	*		X	X	X	3
Northwestern salamander *Ambystoma gracile*					*	+	?	X			X	3	
Shasta salamander *Hydromantes shastae*	C2			T				X				1	
Tailed frog *Ascaphus truei*		C	SC	SC	+	+	*		X	X	X	1,3	
Cascades frog *Rana cascadae*			SC	SC				X			X	1	
Red-legged frog *Rana aurora*			SC	SC			?		X		X	1,3	
Western spotted frog *Rana pretiosa*	Pet	C	SC								X	1	
Foothill yellow-legged frog *Rana boylei*			SC	SC		?			X		X	1,3	
Western toad *Bufo boreas*											X	2	
Western pond turtle *Clemmys marmorata*	C2	T	SC	SC					X		X	1	
Sharp-tailed snake *Contia tenuis*			SC						X			1	

WA = Washington OR = Oregon CA = California

[a]***Federal status:*** E = endangered, T = threatened, C = candidate, C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act, C3 = Taxa which have proven to be more abundant or widespread than previously believed and/or which have no identifiable threats. This status is based only on the most recently published Candidate Notice of Review. PrT = proposed threatened, Pet = petition pending.

[b]***State status:*** WA: C = candidate, M = monitor, X = extirpated, G = game. **OR:** SC = sensitive (critical), SV = sensitive (vulnerable), SR = sensitive (rare), SU = sensitive (undetermined), X = extirpated. **CA:** SCT = state candidate for listing as threatened, SC = species of concern, E = endangered. Source (states): California Department of Fish and Game (1991a, Oregon Department of Fish and Wildlife (1991), Washington Department of Wildlife (1991a. and 1991b).

[c]+ = old-growth associated, * = close old-growth associated, ? = species not studied or data insufficient (see Ruggiero et al. 1991).

[d]***Endemic:*** L = local, B = broadly; (see Ruggiero et al. (1991) and Beatty et al. (1991) for definition and list of endemic species).

[e]***References:*** 1) Beatty et al. (1991). 2) J. Beatty, Oregon State University, Zoology Department, pers. comm. 3) Ruggiero et al. (1991).

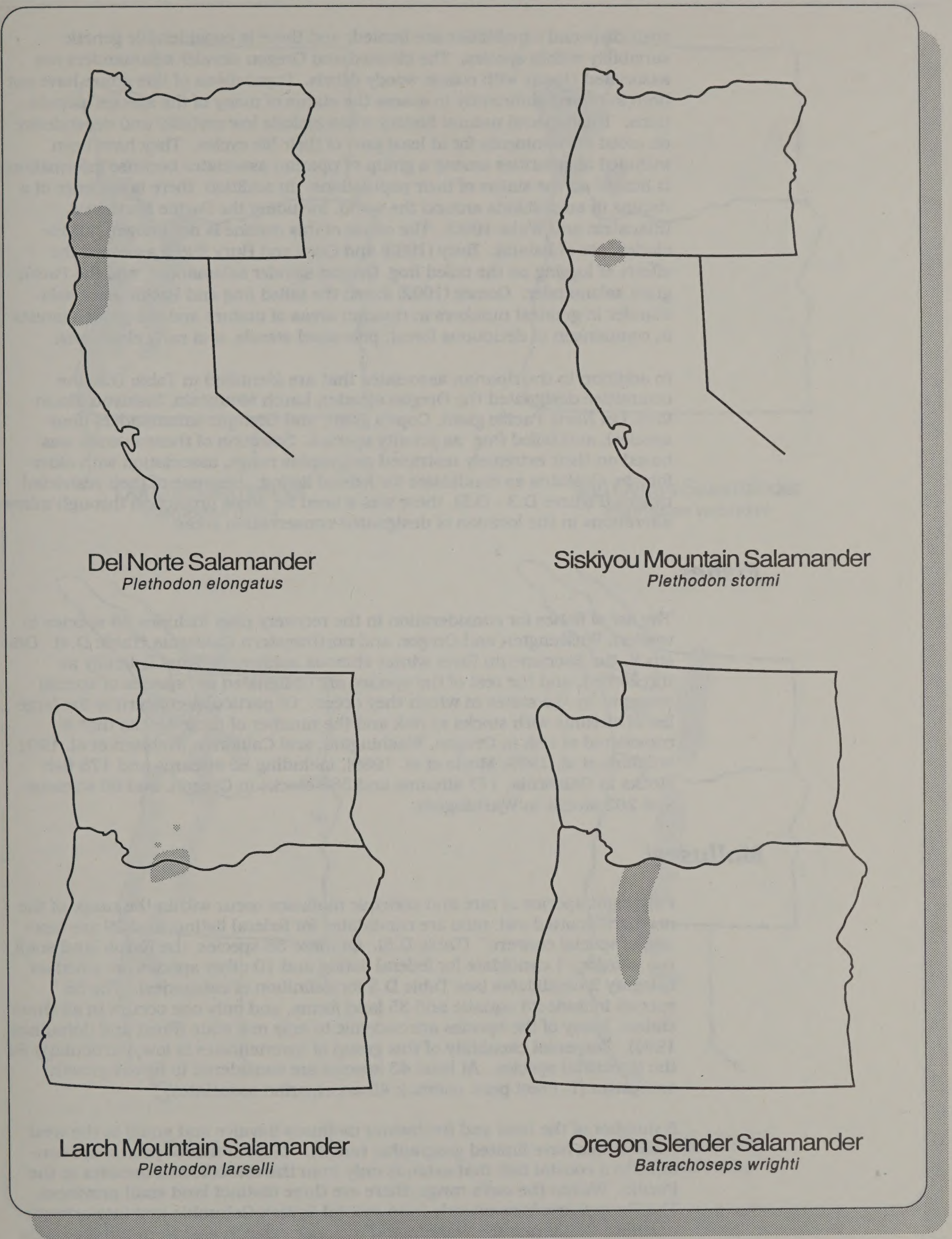

Figure D.3. Geographic range of Del Norte, Siskiyou Mountain, Larch Mountain, and Oregon Slender Salamanders.

their dispersal capabilities are limited; and there is considerable genetic variability within species. The clouded and Oregon slender salamanders are associated closely with coarse woody debris. Populations of this group have not been surveyed sufficiently to assess the status of many of the species' populations. Their special natural history traits include low mobility and dependency on moist environments for at least part of their life cycles. They have been included as priorities among a group of riparian associates because information is limited on the status of their populations. In addition, there is evidence of a decline in amphibians around the world, including the Pacific Northwest (Blaustein and Wake 1990). The cause of this decline is not known, but includes loss of habitat. Bury (1983) and Corn and Bury (1989) assessed the effects of logging on the tailed frog, Oregon slender salamander, and the Pacific giant salamander. Gomez (1992) found the tailed frog and Pacific giant salamander in greatest numbers in riparian areas of mature and old-growth forests in comparison to deciduous forest, pole-sized stands, and early clear-cuts.

In addition to the riparian associates that are identified in Table D.3, the committee designated the Oregon slender, Larch Mountain, Siskiyou Mountain, Del Norte Pacific giant, Cope's giant, and Olympic salamanders (four species), and tailed frog as priority species. Selection of these species was based on their extremely restricted geographic range, association with older forests, or status as candidates for federal listing. Because of their restricted ranges (Figures D.3 - D.5), there was a need for some protection through minor alterations in the location of designated conservation areas.

Fishes

The list of fishes for consideration in the recovery plan includes 28 species in western Washington and Oregon and northwestern California (Table D.4). One stock, the Sacramento River winter chinook salmon, is listed federally as threatened, and the rest of the species are designated as "species of special concern" by the states in which they occur. Of particular concern is the large list of streams with stocks at risk and the number of these stocks that is considered at risk in Oregon, Washington, and California (Nehlsen et al. 1991, Williams et al. 1989, Moyle et al. 1989), including 85 streams and 178 fish stocks in California, 177 streams and 386 stocks in Oregon, and 86 streams and 202 stocks in Washington.

Molluscs[1]

Fifty-eight species of rare and endemic molluscs occur within the range of the northern spotted owl; nine are candidates for federal listing, and 29 are "species of special concern" (Table D.5). Of these 58 species, the Karok land snail is a category 1 candidate for federal listing and 10 other species are rated as category 2 candidates (see Table D.5 for definition of categories). The 58 species include 23 aquatic and 35 land forms, and only one occurs in all three states. Many of the species are endemic to only one state (Frest and Johannes 1991). Dispersal capability of this group of invertebrates is low, particularly for the terrestrial species. At least 43 species are considered to be old-growth associates (T. Frest pers. comm.); 45 are riparian associates.

A number of the land and freshwater molluscs (bivalve and snail) in the west coast states have limited geographic ranges. Most of these species are confined to a coastal belt that extends only from the crest of the Cascades to the Pacific. Within the owl's range, there are three distinct land snail provinces. The Oregon province extends from coastal British Columbia just into extreme northern California; the Washington province extends east from the Cascades crest; and the California province is coastal from northern California.

[1]Largely extracted from information supplied by Terrence Frest of Deixis consultatants (letter of 17 September 1991).

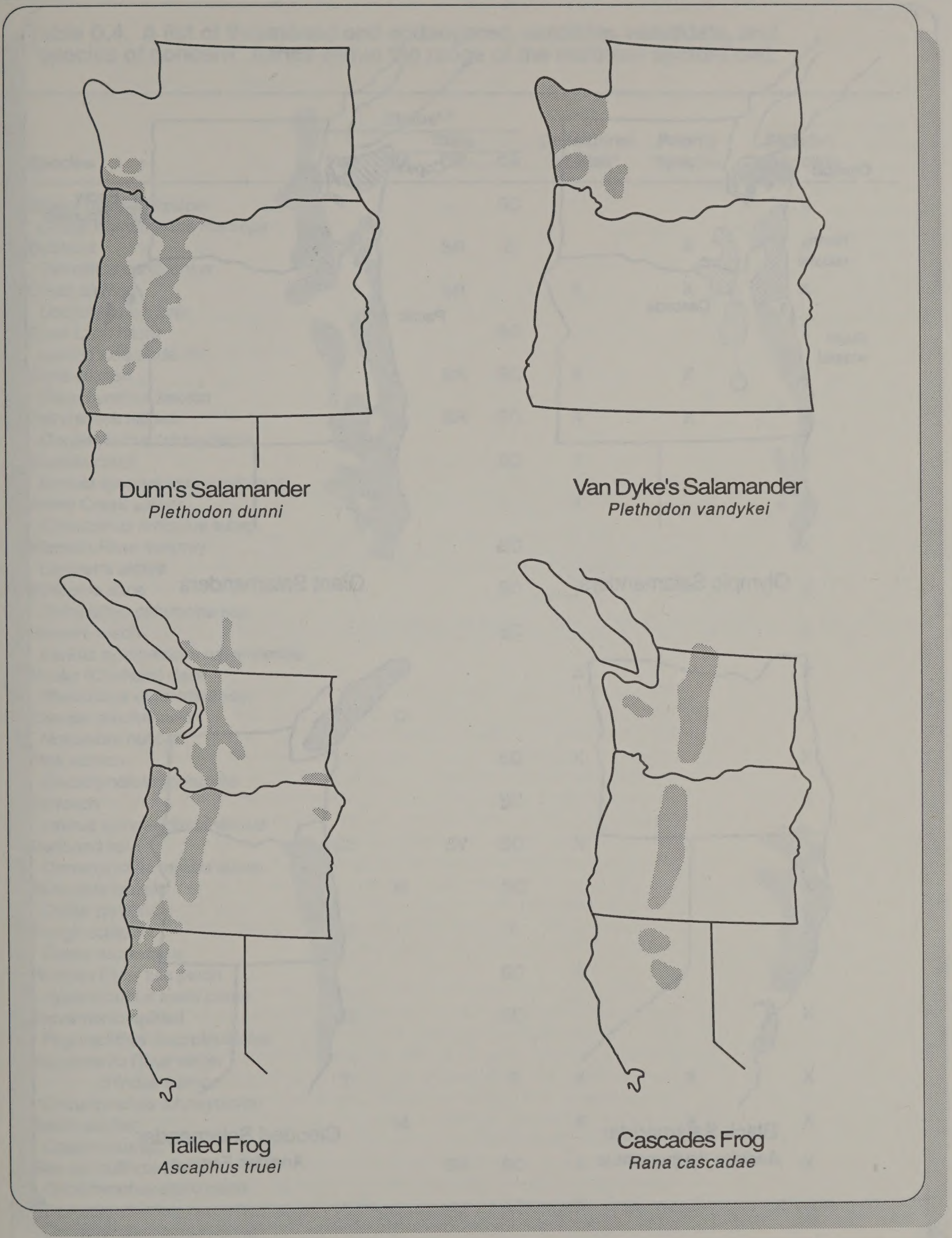

Figure D.4. *Geographic range of Dunn's salamander, Van Dyke's salamander, tailed frog, and Cascades frog in the Pacific Northwest.*

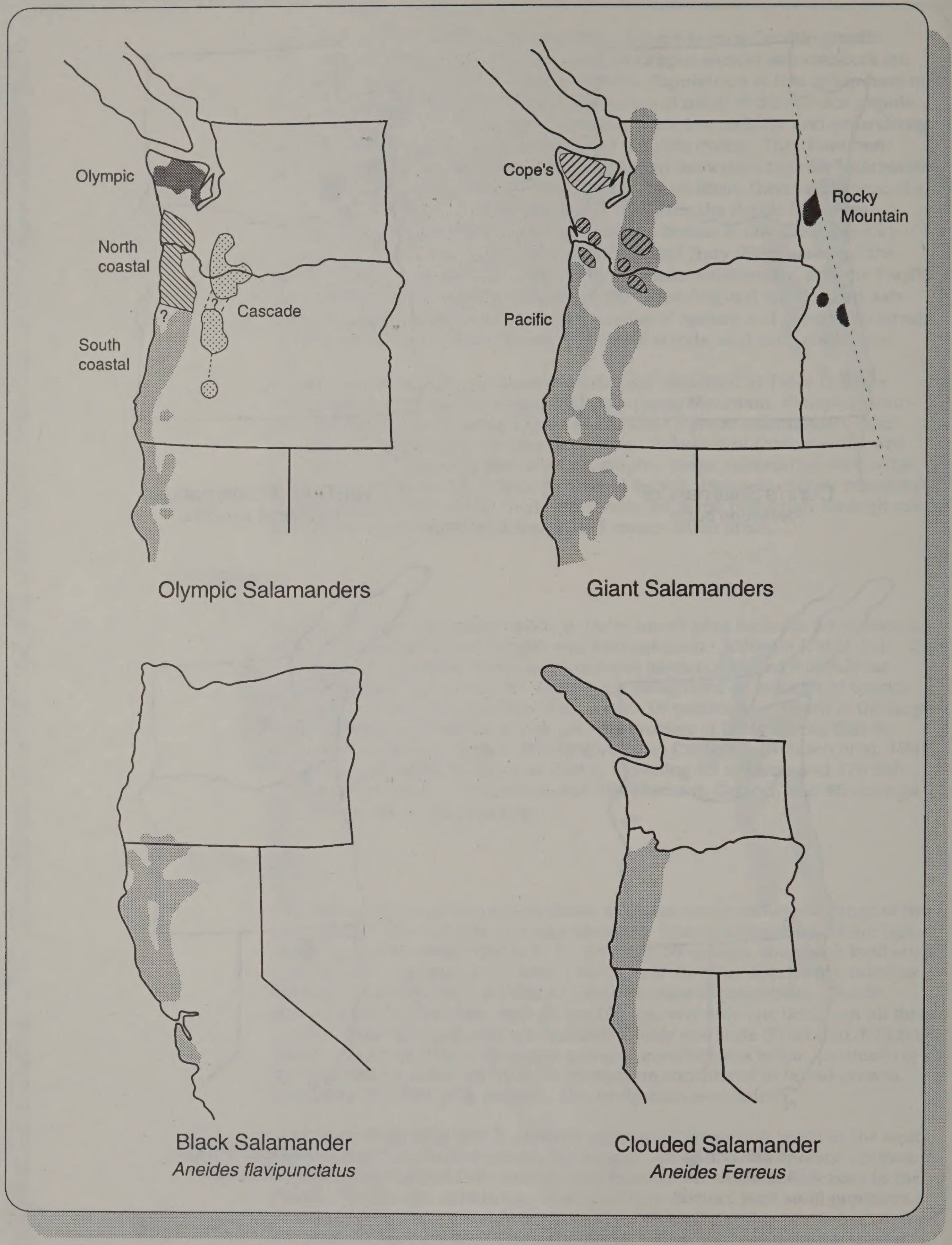

Figure D.5. *Geographic range of Olympic salamanders, giant salamanders, black salamanders, and clouded salamanders.*

Table D.4. A list of threatened and endangered, sensitive, candidate, and "species of concern" fishes within the range of the northern spotted owl.

Species	Status[a,b] Fed	State WA	State OR	State CA	Considered at Risk[c]	Priority Species	Riparian Associate
Bigeye marbled sculpin *Cottus klamathensis macrops*				SC			X
Bull trout *Salvelinus confluentus*	C2		SR	E		X	X
Chum salmon *Oncorhynchus keta*			SR		X	X	X
Clear Lake hitch *Lavinia exilicauda chi*				SC			X
Coho salmon *Oncorhynchus kisutch*			SR	SC	X	X	X
Fall chinook salmon *Oncorhynchus tshawytscha*			SR	SC	X	X	X
Gualala roach *Lavinia symmetricus parvipinnis*				SC	X		X
Jenny Creek sucker *Catostomus rimiculus* subsp.	C2				X		X
Klamath River lamprey *Lampetra similis*				SC			X
Millicoma dace *Rhinichthys cataractae* ssp.				SC			X
Navarro roach *Lavinia symmetricus navarroensis*				SC			X
Nooky (Chehalis) dace *Rhinichthys cataractae* ssp.		M			X		X
Olympic mudminnow *Novumbra hubbsi*		C					X
Pink salmon *Oncorhynchus gorbuscha*				SC	X		X
Pit roach *Lavinia symmetricus mitrulus*				SC			X
Redband trout *Oncorhynchus mykiss* subsp.	C2		SV	SC	X	X	X
Reticulate sculpin *Cottus perplexus*		M		SC			X
Rough sculpin *Cottus asperrimus*	C2			T			X
Russian River tule perch *Hysterocarpus traski pomo*				SC	X		X
Sacramento splittail *Pogonichthys macrolepidotus*	C2			SC			X
Sacramento River winter chinook salmon *Oncorhynchus tshawytscha*	T			E	X	X	X
Salish sucker *Catostomus* sp.		M			X	X	X
Sea run cutthroat trout *Oncorhynchus clarki clarki*			SR	SC	X	X	X
Spring chinook salmon *Oncorhynchus tshawytscha*				SC	X	X	X

continues—

continued—

Species	Status[a,b] Fed	State WA	OR	CA	Considered at Risk[c]	Priority Species	Riparian Associate
Sockeye salmon *Oncorhynchus nerka*					X	X	X
Summer chinook salmon *Oncorhynchus tshawytscha*					X	X	X
Summer steelhead trout *Oncorhynchus mykiss*				SC	X	X	X
Tidewater goby *Eucylogobius newberryi*	C2			SC	X		X
Tomales roach *Lavinia symmetricus* subsp.				SC			X
Umpqua chub *Oregonichthys kalawatseti*			SR				X
Oregon chub *Oregonichthys crameri*	PrE		SR				X
Winter steelhead trout *Oncorhynchus mykiss*					X	X	X

WA = Washington OR = Oregon CA = California

[a]***Federal status:*** E = endangered, T = threatened, C = candidate, C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act. PrE = proposed endangered. Pet = petition pending.

[b]***State status:*** **WA**: C = candidate, M = monitor, X = extirpated, G = game; **OR**: SC = sensitive (critical), SV = sensitive (vulnerable), SR = sensitive (rare), SU = sensitive (undetermined), X = extirpated; **CA**: SCT = state candidate for listing as threatened, SC = species of concern, E = endangered. Sources (states): California Department of Fish and Game (1991a). Oregon Department of Fish and Wildlife (1991), Washington Department of Wildlife (1991a and 1991b).

[c]See Moyle et al. (1989), Nehlsen et al. (1991), Williams et al. (1989).

There are sizable endemic species clusters in the land snail genera *Monadenia, Trilobopsis, Megomphix, Haplotrema, Vespericola*, and *Hemphillia*. Physical factors limiting their distribution include geologic history, substrate (some are restricted to limestone, e.g., the candidate *Monadenia troglodytes*, endemic to the Siskiyou Mountains and the area around Mt. Shasta), moisture requirements, and cover. In general, land snails in this region require relatively undisturbed cover. Most thrive in lowland forests and the areas around springs. Many species seem to be associated specifically with lowland old-growth forests, and most are extremely limited in distribution. The malone jumping slug, *Hemphillia malonei*, occurs only on the slopes of Mt. Hood. The genus *Megomphix* is known only from sites in the Puget Sound region and in the Willapa Hills, of southwest Washington. In recent years, only one site has been found to support *Megomphix hemphilli*.

The delineation of freshwater mollusc provinces is similar to that of land snails. The Pacific drainage is situated similarly to the coastal land snail provinces. The Columbia drainage is a separate unit; and the Interior drainage province intersects the owl range in northern California. Endemic clusters are noted most in the family Hydrobiidae and in the genus *Juga*. The family Lancidae is mostly coastal and occurs mainly in a few streams in southwest Oregon and northwest California. Species confined to single streams or springs are not uncommon. Many small and some large taxa are restricted to particular streams in the area such as, the Rogue and Umpqua systems in Oregon; the Klamath and upper Sacramento in California; the lower Columbia and Columbia Gorge in Washington and Oregon; or to one or a few coastal streams. Generally, molluscs are affected by any increase in siltation, decrease in flow, nutrient enrichment, and damming or other flow impediments. The rare and endemic forms are particularly affected.

Table D.5. A list of molluscs that are candidates for listing and are of special concern in the range of the northern spotted owl.

Species	Status[a] Fed	State WA	State OR	State CA	Old Forest[b] Association	Endemic[b] L	Endemic[b] B	Priority Species	Riparian Associate
Columbia pebblesnail *Fluminicola columbiana*	C2					WA,OR			X
Shortface lanx *Fisherola nuttalli nuttalli*	C3						WA,OR		
Dalles sideband *Monadenia fidelis minor*	C2					WA,OR			
No common name *Monadenia troglodytes chaceana*	C2				X	CA		X	X
Shasta sideband *Monadenia troglodytes troglodytes*	C2				X	CA		X	X
Wintu sideband *Monadenia troglodytes wintu*	C2				X	CA		X	X
Rocky coast sideband *Monadenia fidelis pronotis*	C2					CA		X	X
Trinity bristlesnail *Monadenia setosa*	C2			T	X	CA		X	X
Karok hesperian *Vespericola karokorum*	C1				X	CA		X	X
Barren juga *Juga hemphilli hemphilli*		SC	SC		X	WA,OR		X	X
Dalles juga *Juga hemphilli dallesensis*		SC	SC		X	WA,OR			X
No common name *Juga hemphilli* subsp.		SC	SC		X	WA,OR			X
Brown juga *Juga (J.)* n. sp. 1		SC	SC		X	WA,OR			X
Tall juga *Juga (J.)* n. sp. 3			SC		X	OR			X
No common name *Juga (O.)* n. sp. 1		SC				WA			X
No common name *Juga (O.)* n. sp. 2			SC			OR			X
Scalloped juga *Juga (C.) actifilosa*			SC		X	OR,CA			X
Topaz juga *Juga (C.) occata*			SC			OR			X
No common name *Amnicola (L.)* n. sp.		SC	SC		X	WA,OR			X
Nerite rams-horn *Vorticifex neritoides*		SC	SC			WA,OR		X	
Rotund physa *Physella columbiana*		SC	SC			WA,OR		X	
Vagrant pebblesnail *Fluminicola seminalis*			SC		X	OR,CA			X
Highcap lanx *Lanx alta*			SC		X	OR,CA			
Kneecap lanx *Lanx patelloides*			SC			OR,CA			
Great Basin rams-horn *Helisoma newberryi newberryi*			SC			OR,CA			X
Columbia hesperian *Vespericola columbiana columbiana*		SC	SC			WA,OR			
Malone jumping-slug *Hemphillia malonei*			SC		X	OR		X	X
Panther jumping-slug *Hemphillia pantherina*		SC			X	WA		X	X
Warty jumping-slug *Hemphillia glandulosa glandulosa*		SC	SC		X	WA,OR		X	X
Burrington jumping-slug *Hemphillia barringtoni*		SC			X	WA			X
Blue-gray tail-dropper *Prophysaon coeruleum*		SC	SC		X	WA,OR		X	X
Papillose tail-dropper *Prophysaon dubium*		SC	SC		X	WA,OR		X	X

continues—

continued—

Species	Status[a] Fed	State WA	State OR	State CA	Old Forest[b] Association	Endemic[b] L	Endemic[b] B	Priority Species	Riparian Associate
Columbia sideband *Monodenia fidelis columbiana*		SC	SC		X	WA,OR		X	X
Green sideband *Monadenia fidelis beryllica*			SC		X	OR			X
Traveling sideband *Monadenia fiddelis celeuthia*			SC		X	OR		X	X
Yellow-base sideband *Monadenia fidelis ochromphalous*					X	CA		X	X
Tawny sideband *Monadenia fidelis leonina*					X	CA		X	X
No common name *Monadenia fidelis klamathica*					X	CA		X	X
Klamath sideband *Monadenia churchi*					X	CA			X
Shasta chaparral *Trilobopsis roperi*					X	CA		X	X
Tehama chaparral *Trilobasis tehamana*					X	CA		X	X
Shasta hesperian *Vespericola shasta*					X	CA		X	X
Siskiyou hesperian *Vespericola sierrana*					X	CA		X	X
Large hesperian *Vespericola megasoma euthales*					X	CA		X	X
Oregon megomphix *Megomphix hemphilli*		SC	SC		X	WA,OR		X	X
Willamette floater *Anodonta wahlametensis*		SC	SC				X		
No common name *Juga (Oreobasis) chacei*					X				X
No common name *Juga (Oreobasis) orickensis*					X				X
Rotund lanx *Lanx subrotundata*					X				
No common name *Monadenia callipeplus*					X			X	X
No common name *Monadenia cristulata*					X			X	?
No common name *Monadenia fidelis salmonensis*					X			X	X
No common name *Monadenia fidelis scottiana*					X			X	?
No common name *Monadenia rotifera*					X			X	?
Hooded lancetooth *Haplotrema voyanum*					X				?
Oregon shoulderband *Helminthoglypta hertleini*									X
Evening fieldslug *Deroceras hesperium*					X			X	X
California floater *Anodonta californiensis*	C2	SC	SC	SC			X		X

WA = Washington OR = Oregon CA = California

[a]*Status:* E = endangered, T = threatened, C = candidate, C1 = cateorgy 1 candidate, taxa for which the U.S. Fish and Wildlife Service has sufficient information to support a proposal to list as threatened or endangered under the Endangered Species Act. C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act. C3 = Taxa which have proven to be more abundant or widespread than previously believed and/or which have no identifiable threats. This status is based only on the most recent published Candidate Notice of Review. SC = species of concern (Frest and Johannes 1991).

[b]Frest and Johannes (1991).

L = local B = broadly

Some examples of species with limited distribution include a largely undescribed species cluster in *Juga*, restricted to a few streams in the Western Columbia Gorge, Washington, and Oregon; the species *Juga* (C.) *acutifilosa*, known from only eight spring sites in northern California and southwest Oregon; and *Vorticifex neritoides* and *Physella columbiana*, both restricted to the lower 60 miles of the Columbia River. Narrowly endemic molluscs often are associated closely with other endemic groups or species. For example, endemic arthopods and molluscs frequently inhabit the same springs in the Columbia River Gorge, and *Fluminicola* species are associated with the Jenny Creek sucker and redband trout.

In land and freshwater forms, most narrow endemics have been discovered only within the last decade and presumably many more will be found. Recently (spring and summer 1991), for example, a new endemic cluster of five *Fluminicola* species was discovered that is restricted to two creeks and associated springs on the California-Oregon border in the Siskiyou Mountains.

Arthropods and Other Invertebrates

The litter and soil of the forest floor are the site of some of the highest biological diversity found anywhere. Scientists estimate that about 8,000 species of arthropods inhabit a single study site in an Oregon old-growth forest, most of them in the soil (J. Lattin, A. Moldenke, Oregon State University, pers. comm.). To date taxonomists have been able to identify 3,400 arthropod species at the H.J. Andrews Experimental Forest (about 45 miles east of Eugene, Oregon) (Parsons et al. 1991). Invertebrates of the forest soil are critical in determining the long-term productivity of the forest. The soil under a square yard of forest may hold as many as 200,000 mites from a single suborder, plus tens of thousands of other mites, beetles, centipedes, pseudoscorpions, springtails, and "microspiders." Most of these species probably are undescribed. The structure and function of temperate forest soils may be determined by the dietary habits of the soil arthropods. They are the basic consumers of the forest floor where they ingest and process massive amounts of organic litter and debris, from large logs to bits of moss. The richness of arthropod species in old-growth forests suggests a great number of different processes and functions, but little is known about how these arthropods interact and survive. There are a number of species prominent in older forests that occur infrequently in young forests; further study undoudtedly will reveal others (A. Moldenke, Oregon State University, pers. comm.).

Fifty-nine species of arthropods within the range of the northern spotted owl are listed as "species of special concern" or category 2 candidate species for federal listing (Table D.6). Thirty-four species are category 2 candidate species and the remainder are designated "species of special concern". Thirty-four of the species are aquatic and 25 are terrestrial forms. Twenty-two of the species are endemic to Oregon; six to California, and none is found in all three states. This list is not exhaustive, but is representative.

Several significant points can be made about the arthropods as a group that are relevant to the recovery plan for spotted owls. First, many species are flightless, which means that their dispersal capabilities are limited. Second, the flightless condition is believed to reflect habitat stability and permanence over a long time period. Some old forest associates have highly disjunct distributions and are found only in undisturbed forests. They share similar distribution patterns on the west side of the Cascade Mountains from British Columbia south to southern Oregon and northern California (i.e., they are

endemic to the Pacific Northwest). Many of the species native to this region have not been described or named, and the number of known species probably represents less than half of the estimated species (J. Lattin, Oregon State University, pers. comm.).

Twenty-three species of terrestrial arthropods, most of which are wingless and flightless, are considered to be old-growth associates (J. Lattin, Oregon State University, pers. comm.). Camel crickets of the genus *Pristoceuthophilus* and *Tropidischia xanthostoma* are found in old-growth forests in the hemlock and silver-fir zones, and they occur on the forest floor under logs and debris. Some species in this group of older-forest associates belong to very small genera and are considered rare, including *Boreostolis americanus, Metrius contractus, Promecognathus laevissimus, Zacotus mathewsii,* and *Lobosoma horridum.* All of these species belong to genera that have only one or two described species and are often relics of past geologic history. One unique predator-prey relationship exists in this group between the prey species *Harpaphe haydeniana* and the predator *Promecognathus laevissimus. H. haydeniana* is a distinctively marked millipede that is a very important shredder of litter and, therefore, an initiator of nutrient cycling. The species is marked brightly and produces hydrocyanic gas when disturbed. The production of cyanide is a deterrent to most predators except *P. laevissimus*, which is specialized for feeding on this millipede by its tolerance of cyanide gas. *P. laevissimus* is a terrestrial ground beetle found in mature forests on the west side of the Cascade Mountains.

There are also 17 species of insects from 13 families (Table D.7) that are associated with coarse woody debris in western coniferous forests (J. Lattin, Oregon State University, pers. comm.). The decomposition of coarse woody debris is a slow process in a natural ecosystem, and in the Pacific Northwest many hundreds of invertebrate species have evolved to utilize logs for food or habitat (Schowalter et al. 1991, Parsons et al. 1991, Moldenke, unpublished data). Though many of these species may have similar ecologic roles, the natural process is not understood enough to know whether some or many are redundant for system function. However, the diversity of species itself may be a useful management tool to detect changes in the effects that logs may be exerting on the old-growth system.

Vascular Plants

One hundred and forty-four species of vascular plants that occur within the range of the northern spotted owl are older-forest associates or are listed as "species of special concern" by one or more of the three states (Table D.8). Seventy-six of the species on the list are associated with older forest ecosystems (Ruggiero et al. 1991b). These plants include several species that have generated significant interest including the Pacific yew and Port Orford cedar. The Pacific yew especially is of interest because of the chemical taxol, which can be extracted from yew bark and is being tested as an anti-cancer drug. Port Orford cedar occurs only in a restricted area of northwestern California and southwestern Oregon and is susceptible to root disease. No opportunities were identified specifically to provide measures to benefit these species, but management of habitat for owls is likely to provide them with habitat support.

Fungi and Lichens

The list of fungi and lichens contains eight species. These species were identified as older-forest associates by Ruggiero et al. (1991b), and of these, two are species of special concern in one or more of the three states. Lichens of the

Table D.6. List of threatened, endangered, candidate, sensitive, or older-forest associated arthropods in the range of the northern spotted owl[a].

Species	Status[b] Fed	State WA	State OR	State CA	Old Forest Associate	Riparian Associate
Insects						
Orthoptera:						
Boonacris alticola					X	
Pristoceuthophilus celatus					X	
Pristoceuthophilus cercalis					X	
Pristoceuthophilus sargentae					X	
Tropidischia xanthostoma					X	
Hemiptera:						
Boreostolis americanus					X	
Plinthisus longisetosus					X	
Thylochromus nitidulus					X	
Eurychilopterella sp.					X	
Phytocoris nobilis					X	
Pithanus maerkelii					X	
Polymerus castellaeni					X	
Vanduzeenia borealis					X	
Acalypta lillianis					X	
Acalypta saundersi					X	
Derephysia foliacea					X	
Coleoptera:						
Cychrus tuberculatus					X	
Metrius contractus					X	
Promecognathus laevissimus					X	
Zacotus mathewsii					X	
Omus dejeani					X	
Lobosoma horridum					X	
Acneus beeri	C2					X
Acneus burnelli	C2					
Cicindela columbica						X
Pterostichus rothi						
Plecoptera:						
Nemoura wahkeena	C2					X
Solperia fenderi	C2					X
Trichoptera:						
Eobrachycentrus gelidae	C2					X
Agapetus denningi	C2					X
Homoplecta schuhi	C2					X
Ochrotrichia alsea	C2					X
Lepidostoma goedeni	C2					X
Apatania tavaia	C2					X
Farula davisi	C2					X
Farula jewetti	C2					X
Farula reaperi	C2					X
Limnephilus alconura	C2					X
Limnephilus atereus	C2					X
Neothremma andersoni	C2					X
Oligophlebodes mostbento	C2					X
Philocasca oron	C2					X
Dolophilodes oregona	C2					X
Tinodes siskyou	C2					X
Rhyacophila ambilis	C2					X

continues—

continued—

Species	Status[b] Fed	State WA	State OR	State CA	Old Forest Associate	Riparian Associate
Rhyacophila colonus	C2					X
Rhyacophila fenderi	C2					X
Rhyacophila haddocki	C2					X
Rhyacophila lineata	C2					X
Rhyacophila mosana	C2					X
Rhyacophila unipunctata	C2					X
Desmona bethula	C2					X
Cryptochia shasta	C2					X
Goeracea oregona	C1					X
Neothremma genella	C2					X
Neothremma siskyou	C2					X
Ochrotrichia vertreesi	C2					X
Abellan hydropsyche	C2					X
Diplopoda:						
Harpaphe haydeniana					X	

WA = Washington OR = Oregon CA = California
Federal status: C = candidate, C1 = category 1 candidate, taxa for which the U.S. Fish and Wildlife Service has sufficient information to support a proposal to list as threatened or endangered under the Endangered Species Act. C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act.
[a]Information from J.D. Lattin, Oregon State University, Administrative Record.

Table D.7. Insects associated with course woody debris in western Oregon Cascades.

Species	Feeding Habitats[a]	Stage in Log[b]	Recorded Hosts/Habitats[c]	Reference[d]
Buprestis aurulenta L.	Xylo	Imm	Psme, *Abies, Pinus, Picea*	1
Leptura obliterata Hald.	Xylo	Imm	Psme, Tshe, *Abies, Picea, Pinus, Sequ.*	1,4
Spondylis upiformis Mann.	Xylo	Imm	roots of pine or fir ?	4
Silvanus bidentatus F.	Pred-Scav?	Ad+Imm	subcortical	3
Cossonus ponderosai VanD.	Xylo?	Ad+Imm	under bark of *Pinus*	1,3
Pissodes piperi Hopkins	Xylo?	Imm	*Abies;* root crown of damaged trees	1
Platycerus orgeonensis Westw.	Xylo	Ad?+Imm	rotting *Quercus, Acer, Alnus, Fraxinus*	1
Platypus wilsoni Swaine	Xylo-Fung	Ad+Imm	Psme, *Abies*, Tshe	1
Dendroctonus pseudotsugae Hopk.	Xylo	Ad+Imm	Psme, Tshe, *Larix;* under bark	2
Gnathotrichus retusus (LeC.)	Xylo-Fung	Ad+Imm	Psme, *Pinus, Picea, Alnus, Populus;* in sapwood	2
Trypodendron lineatum (01.)	Xylo-Fung	Ad+Imm	Psme, *Abies*, Tshe, *Picea, Pinus*, Thpl; in sapwood	1,2
Ostoma ferruginea L.	Fung	Ad+Imm	Fung-Polyporaceae under bark	3
Medetera aldrichii Wheeler	Pred	Imm	Prey-bark beetles and woodborers	1
Xylophagus cinctus DeGeer	Pred	Imm	under bark	
Camponotus spp.	Pred-Scav?	Ad+Imm	mine wood of various conifers	1
Urocerus albicornis (F.)	Xylo-Fung	Imm	*Abies*, Psme, Tshe, Thpl, *Pinus, Picea*	1
Zootermopsis angusticollis (Hagen)	Xylo	Ad+Imm	many kinds of wood	1

[a]Xylo = feeds on wood. Pred = predaceous. Fung = fungi. Scav = scavenger.
[b]Ad = adult. Imm = immature.
[c]Psme = *Pseudotsuga menzeisii*, Thpl = *Thuya plicata*, Tshe = *Tsuga heterophylla*, Sequ = *Sequoia*.
[d]See J. D. Lattin, Administrative Record.

Table D.8. A list of candidate, sensitive, and old-growth associated plants within the range of the northern spotted owl.

Species	Status[a,b] Fed	State WA	State OR	State CA	Old Forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority Species	Riparian Associate	References[e]
Vascular Plants:												
Pacific yew *Taxus brevifolia*					*	*	*			X		2
Port Orford cedar *Chamaecyparis lawsoniana*						+	+	X		X		
Common pipsissiwa *Chimaphilia umbellata*					+	+						1,2
Thin-leaved huckleberry *Vaccinium membranaceum*					+	?						2
Fringed pine-sap *Pleuricospora fimbriolata*		S			?	?	+					1,2
Clackamas corydalis *Corydalis aquae-gelidae*	C2	T	C						X		X	
Boreal bedstraw *Galium kamtschaticum*		S			+				X			
Spleenwort-leaved goldthread *Coptis asplenifolia*		S			+			X			X	
Wenatchee larkspur *Delphinium viridescens*		E			+							
Clustered lady's slipper *Cypripedium fasciculatum*		T	C		+	+						
Oregon checker-mallow *Sidalcea oregana calva*		T			+			X				
Pink fawn lily *Erythronium revolutum*		S			+				X			
Pine broomrape *Orobanche pinorum*		S			+							
Pinefoot *Pityopis california*					?	?	+	X				2
Twin flower *Linnaea borealis*					*	*						2
Rattlesnake plantain *Goodyera oblongifolia*					+	+	+					1,2
Wild ginger *Asarum hartwegii*						+	+					2
Vanilla leaf *Achlys triphylla*						*	+					1,2
Queen's cup *Clintonia uniflora*					+	?	+					2
Purple coral-root *Corallorhiza mertensiana*					+		+					2
Bunch berry *Cornus canadensis*					*	+	?					2
Inside-out flower *Vancouveria hexandra*						+	+		X			1,2
Waldo rock cress *Arabis aculeolata*	C3								X			
McDonald's rock cress *Arabis macdonaldiana*	E			E					X			
Preston Peak rock cress *Arabis serpentinicola*	C2							X				
Klamath manzanita *Arctostaphylos klamathensis*	C2											
Bastard kentophyta *Astragalus tegetarioides*	C2		C								X	
Bensoniella *Bensoniella oregana*	C2		C	R								
Green's mariposa lilly *Calochortus greenei*	C2		C									
The Cedars globe-lilly *Calochortus raichei*	C2											
Siskiyou mariposa lilly *Calochortus persistens*	C2			R								

continues—

continued—

Species	Fed	Status[a,b] State WA	OR	CA	Old Forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority Species	Riparian Associate	References[e]
Swamp harebell *Campanula californica*	C2										X	
Wilkin's harebell *Campanula wilkinsiana*	C3											
Purple toothwart *Cardamine gemmata*	C2		C						X			
Pallid birds-beak *Cordylanthus tenus pallescens*	C2											
Mt. Eddy draba *Draba carnosula*	C2											
Siskiyou willow herb *Epilobium siskiyouense*	C3		C									
Trinity buckwheat *Eriogonum alpinum*	C2			E								
Klamath Mt. buckwheat *Eriogonum hirtellum*	C3											
Waldo buckwheat *Eriogonum pendulum*	C3								X			
Umpqua green gentian *Frasera umpquaensis*	C2		C									
Scott Mt. bedstraw *Galium serpenticum scotticum*	C3							X				
Mendocino gentian *Gentiana setigera*	C2		C									
Boggs Lake hedge-hyssop *Gratiola heterosepala*	C2		C	E							X	
Henderson's horkelia *Horkelia hendersonii*	C2		C									
Pickering's ivesia *Ivesia pickeringii*	C2							X				
Two-flowered lathyrus *Lathyrus biflorus*	C2							X				
Heckner's lewisia *Lewisia cotyledon heckneri*	C3											
Stebbin's lewisia *Lewisia stebbinsii*	C2											
Howell's (Mt. Tedoc) linanthus *Linanthus nuttallii howellii*	C2							X				
Peck's lomatium *Lomatium peckianum*	C3											
Anthony Peak lupine *Lupinus antoninus*	C2											
The Lassics lupine *Lupinus constancei*	C2							X				
Stebbin's madia *Madia sebbinsii*	C3							X				
Egg Lake (Pigmy) monkey flower *Mimulus pygmaeus*	C2		C								X	
The Lassics sandwort *Minuartia decumbens*	C2							X				
Scott Mt. (Trinity) phacelia *Phacelia dalesiana*	C2											
Scott Valley phacelia *Phacelia greenei*	C2											
Yreka phlox *Phlox hirsuta*	C1			E				X				
Lassen County bluegrass *Poa fibrata*	C2											
Small-headed sanguisorba *Sanguisorba officinalis microcephala*												
Tracy's sanicle *Sanicula trayci*	C2											
Pale yellow stonecrop *Sedum laxum flavidum*	C3											
Applegate stonecrop *Sedum oblanceolatum*	C2		C									
Canyon Creek stonecrop *Sedum obtusatum paradisum*	C2											
Small star-fruited stonecrop *Sedum radiatum depauperatum*	C2											

continues—

continued—

Species	Status[a,b] Fed	State WA	State OR	State CA	Old Forest Association[c] WA	Old Forest Association[c] OR	Old Forest Association[c] CA	Endemic[d] L	Endemic[d] B	Priority Species	Riparian Associate	References[e]
Red Mountain catchfly *Silene campanulata campanulata*	C1			E				X				
Short-petaled campion *Silene invisa*	C3											
Somes Bar campion *Silene marmorensis*	C2											
Howell's jewelflower *Streptanthus howellii*	C3								X			
Howell's tauschia *Tauschia howellii*	C2		C									
Trail plant *Adenocaulon bicolor*						+	+					1,2
Sugar stick *Allotropa virgata*					?	?	+					1,2
Dogbane *Apocynum pumilum*							+					1
Ground cone *Boschniakia strobilacea*							+					1
Bromegrass *Bromus orcuttianus*							+					1
Hareball *Campanula prenanthoides*							+					1
Pipsissewa *Chimaphila menziesii*							+					1
Goldthread *Coptis laciniata*						+	+					1,2
Hazelnut *Corylus cornuta*							+					1
Fairy bell *Disporum hookeri*							+					1
Shield fern *Dryopteris arguta*							+					1
Phantom orchid *Eburophyton austinae*							+					1
Crinkleawn fescue *Festuca subuliflora*							+					1
No common name *Linnea borealis longifolia*							+					1
Redwood sorrel *Oxalis oregana*							+					1
No common name *Smilacina racemosa*							+					1
Snowberry *Symphoricarpus rivularis*							+					1
Wake-robin *Trillium ovatum*							+					1
Pussytoes *Antenaria suffrutescens*	C3											1
No common name *Happlopappus racemosa congestus*	C3											1
Siskiyou monardella *Monardella purpurea*	C3											1
Peck's sanicle *Sanicula peckiana*	C3											1
No common name *Asarum caudatum*							+					2
No common name *Calypso bulbosa*							+					2
No common name *Pyrola asarifolia*						+						2
No common name *Synthyris reniformis*					?	+						2
Hardy Creek barberry *Berberis nervosa mendocinensis*	C2											
Crater Lake (pumice) grapefern *Botrychium pumicola*	C1		C									
Indian Valley brodiaea *Brodiaea coronaria rosea*	C2											
Arid northern clarkia *Clarkia borealis*	C2											

continues—

continued—

Species	Status[a,b] Fed	State WA	State OR	State CA	Old Forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority Species	Riparian Associate	References[e]
Silky cryptantha *Cryptantha crinita*	C2											
Mendocino cypress *Cupressus pygmaea*	C2											
Red Mt. (Kellogg's) buckwheat *Eriogonum kelloggii*	C1			E								
Milo Baker's lupine *Lupinus milo-bakeri*	C2			T								
Mendocino bush-mallow *Malacothamnus mendocinensis*	C2											
Red Mountain stonecrop *Sedum laxum eastwoodiae*	C1											
Crater Lake rock cress *Arabis suffrutescens horizontalis*	C2		C									
Gorman aster *Aster gormanii*	C2		C									
Crater Lake collomia *Collomia mazama*	C2		C									
Howell's howellii *Erigeron howellii*	C2		C									
Howell's microseris *Microseris howellii*	C2		C									
Barrett's penstemon *Penstemon barrettiae*	C2		C									
Peck's penstemon Penstemon peckii	C2		C									
Bristly sidalcea *Sidalcea setosa*	C2											
Pale blue-eyed grass *Sisyrinchium sarmentosum*	C2		C									
Western sophora *Sophora leachiana*	C2		C									
Oregon sullivantia *Sullivantia oregana*	C2		C									
Wayside aster *Aster vialis*	C2		C									
Peck's milk-vetch *Astragalus peckii*	C2		C									
Howell's mariposa lily *Calochortus howellii*	C2		C									
Green-tinged paintbrush *Castilleja chlorotica*	C2		C									
Gentner's mission-bells *Fritillaria gentneri*	C2		C									
Purdy's lewisia *Lewisia cotyledon purdyi*	C2		C									
Bellinger's meadowfoam *Limnanthes floccosa bellingeriana*	C2		C									
Cusick's lupine *Lupinus cusickii*	C2		C									
Beardtongue *Penstemon glaucinus*	C2		C									
Western senecio *Senecio hesperius*	C2		C									
Obscure Indian paintbrush *Castilleja cryptantha*	C2											
Reedgrass *Calamagrostis tweedyi*	C2											
Showy stickweed *Hackelia venusta*	C1											
Hinds' walnut *Juglans hindsii*	C2											
Gairdner's yampah *Perideridia gairdneri gairdneri*	C2											
Bolander's beach pine *Pinus contorta bolanderi*	C2											
Northcoast semaphore grass *Pleuropogon hooverianus*	C2			R								

continues—

continued—

Species	Fed	Status[a,b] State WA	OR	CA	Old Forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority Species	Riparian Associate	References[e]
Columbia yellow-cress *Rorippa columbiae*	C2		C									
Tamalpais streptanthus *Streptanthus batrachopus*	C2											
Pit River jewelflower *Streptanthus ssp.*	C2											
Oat grass *Festuca californica*							+					1
Bedstraw *Galium aparine*							+					1
Iris *Iris tenuissima*							+					1
Melic grass *Melica subulata*							+					1
Snowberry *Symphoricarpus mollis*							+					1
Fungi and Lichens:												
No common name *Elaphomyces granulatus*						+						
No common name *Elaphomyces muricatus*						+						
No common name *Hysterangium crassirhachis*						+						
No common name *Hysterangium setchelii*						+						
No common name *Rhizopogon atroviolaceus*						+						
No common name *Tuber rufum*						+						
No common name *Oxyporus nobilissimus*		S				+						
No common name *Lobaria oregana or pulmonaria*		S			*	*						2

WA = Washington OR = Oregon CA = California

[a]***Federal status:*** E = endangered, C = candidate, C1 = category 1 candidate, taxa for which the U.S. Fish and Wildlife Service has sufficient information to support a proposal to list as threatened or endangered under the Endangered Species Act. C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act. C3 = taxa which have proven to be more abundant or widespread than previously believed and/or which have no identifiable threats. This status is based only on the most recently published Candidate Notice of Review.

[b]***State status:*** **CA**: E = endangered, T = threatened, R = rare; **WA**: E = endangered, T = threatened, S = sensitive; **OR**: C = critical. Sources (State): California Department of Fish and Game (1991b), Oregon Natural Heritage Program (1991), Washington Natural Heritage Program (1990).

[c]+ = old-growth associated, * = close old-growth associated, ? = species not studied or data insufficient (see Ruggiero et al. 1991).

[d]***Endemic:*** L = local, B = broadly (see Ruggiero et al. (1991) for definition and list of endemic species).

[e]***References:*** 1) Bruce Bingham, Old-growth Douglas-fir Program, USFS, Pacific Southwest Research Station, Arcata, California (see administrative record). 2) Ruggiero et al. 1991.

genus *Lobaria* occur primarily in the canopy of coniferous forests, and their abundance in these canopies becomes greater as a stand develops into an old-growth forest. These organisms are characteristic of older forests in the Pacific Northwest and provide important food for several animal species, most notably ungulates and northern flying squirrels. These food sources are particularly important during the winter when other foods are scarce. The most noble polypore (*Oxyporus nobilissimus*) has been found only three times and was associated with older forests on each occasion.

The role of mycorrhizal fungi in coniferous forests is important to ecosystem function (Trappe and Fogel 1977) because of the symbiotic relationship between truffle fungi and the roots of vascular plants. Each organism derives a benefit from the relationship; the fungi take up nutrients such as potassium, phosphorus, nitrogen, and sodium, and these are translocated to the associated coniferous trees. Conversely, the fungi depend on the host tree for phytosynthates of carbon. Small animals eat truffle fungi and disperse their

spores (Maser et al. 1978b). Mushrooms also are consumed which compliments spore dispersal by wind. The functional role of mycorrhizal fungi in coniferous forests has been described by Trappe and Fogel (1977) and their characterization of this role is quoted below:

> "The great majority of vascular plants have evolved to a dependence on mycorrhizae as the most metabolically active parts of their root systems. Most woody plants require mycorrhizae to survive, and most herbaceous plants need them to thrive. Despite their relatively small biomass, the mycorrhizal fungi (mycobionts) are vital for uptake and accumulation of ions from soil and translocation to hosts because of their high metabolic rate and strategically diffuse distribution in the upper soil layers. The mycobionts produce enzymes, auxins, vitamins, cytokinins, and other compounds that increase rootlet size and longevity. They commonly protect rootlets from pathogens. They absorb and translocate water to the host. Most mycobionts, in turn, depend on their hosts for carbon products. Except for orchid mycobionts, few are capable of decomposing organic matter, although their respiration contributes significantly to evolution of carbon dioxide from soil. The fungal mycelium and sporocarps are sources of accumulated nutrients and energy for decomposers and consumers. Nutrients and carbon can be transferred from one vascular plant to another by a shared mycorrhizal mycelium. The several thousand species of fungi believed to form mycorrhizae encompass great physiological diversity. They differ in numerous ways, including degree of host specificity, resistance to environmental extremes, selectivity in ion uptake, and production of biologically active products. Net effects of one mycobiont on a host can differ from those of another, although overall functions are shared by most. As key links in below ground nutrient and energy cycling, mycorrhizae and their mycobionts can be ignored only at substantial peril of reaching unreal conclusions about ecosystem processes."

This explanation gives some sense of the importance of fungi in the function of coniferous forests. In addition, two of the spotted owl's primary prey species (northern flying squirrel and red-backed vole) consume fungi as their primary food (Maser et al. 1978b), so that fungi are an important link in the owl's food chain.

Summary

Three hundred and sixty-four species of plants and animals were considered in the recovery planning process for the northern spotted owl (Table D.9). Of those, five are listed federally as threatened or endangered, more than 150 are candidates for listing; 30 are listed as threatened or endangered in one or more of the three states, and 131 are "species of special concern" in at least one of the states. In addition, the list of 28 fish species includes approximately 766 stocks that are considered at risk and may become candidates for listing in the future. More than 100 of the species are narrowly or broadly endemic to the Pacific Northwest and 194 are associated with older forests. The large number of candidates for federal listing, species of special concern, and endemic species emphasizes the importance of considering other species in the owl recovery plan. In addition, the large number of riparian associated species (132), plus the number of fish stocks at risk emphasize the importance of riparian areas.

Of the 364 species considered, the committee identified 18 priority species (marbled murrelet, bald eagle, goshawk, marten, fisher, grizzly bear, gray wolf, Oregon slender salamander, Siskiyou Mountain salamander, Larch Mountain salamander, Del Norte salamander, Olympic salamander—four species, Pacific giant salamander, Cope's giant salamander, tailed frog); a larger group of riparian-associated species including fishes, amphibians, mammals, insects, and molluscs; and a small group of prey species for the northern spotted owl (flying squirrel, bushy-tailed woodrat, dusky-footed woodrat, red tree voles, and western red-backed vole). Of these, the marbled murrelet and the numerous fish stocks were given highest priority. The bald eagle, goshawk, marten, fisher, grizzly bear, and gray wolf were assigned lower priority, because the bald eagle, grizzly bear and gray wolf already are protected under the Endangered Species Act; and sufficient information was lacking on goshawks, marten, and fisher to modify the recovery plan. The 10 salamanders have extremely restricted home ranges and were considered in the delineation of DCAs for the owl. The committee assumed that spotted owl prey and the older-forest associated species would benefit from a plan that conserved older forests for owls.

Table D.9. Summary of 361 plants and animals considered in the recovery planning process for the northern spotted owl.

Species (Number)	Federally Listed	Candidate for Listing	State Listed	Species of Special Concern	Endemic[a]	Older Forest Associate	Riparian Associate
Birds (23)	1	2	4	8	4	20	3
Mammals (18)	2	2	3	9	8	12	4
Amphibians[b] (26)	0	7	3	16	20	12	12
Fish (28)	1	7	3	25	N/A	N/A	28
Molluscs (58)	0	10	1	29	47	43	45
Insects (59)	0	34	0	[c]	[c]	23	34
Vascular plants (144)	1	93	16	42	23	76	6
Fungi and Lichens (8)	0	0	[c]	2	[c]	8	0
TOTAL (N=364)	5	155	30	131	102	194	132

[a]either locally or broadly endemic.
[b]Includes two reptiles — the sharp-tailed snake and western pond turtle.
[c]Unknown.

Biology of Owl Prey, Older Forest Associates, and Riparian Ecosystems

Unique Food Webs of Older Forest Ecosystems

Temperate coniferous forests of the Pacific Northwest are unique among the forests of the world for a number of reasons (Waring and Franklin 1979), and the structural and functional diversity of these forests provides habitat for a diverse array of plants and animals. Of particular interest is the high species richness of birds, mammals, amphibians, molluscs, arthropods, and plants that characterize the complex food webs in these forests. Among the vertebrate and invertebrate fauna, there are numerous species of granivores, detritivores, folivores, herbivores, fungivores, and a diverse group of aquatic species including fishes, amphibians, and arthropods (Harris 1984:52). The mammalian order of insectivores (shrews and moles) is represented in the Pacific Northwest forests by more species than in any other temperate or boreal forest in North America. Two of the most important food webs in these coniferous forests include foliage and fungi eating mammals (referred to as folivores and fungivores, respectively) that are prey for the northern spotted owl.

Two folivores that inhabit coniferous forests in the Pacific Northwest belong to the genus *Phenacomys* (*Arborimus*), which is restricted to western Oregon and northwest California (Figure D.1a). The red tree voles (*Phenacomys longicaudus, P. pomo*) are particularly unusual among rodents in that they live almost their entire life in the canopy of Douglas-fir trees. These species are associated with old-growth Douglas-fir forests (Aubry et al. 1991, Ruggiero et al. 1991b), although they do occur in lower numbers in forests of other tree species and younger successional stages. The diet of the *P. longicaudus* is almost entirely needles of Douglas-fir (Maser et al. 1981). In turn, the red tree vole is one of the primary prey species of the northern spotted owl in the Cascade Mountains of Oregon (Forsman et al. 1984). The third species in this genus is the white-footed vole (*Phenacomys albipes*), an extremely rare species that is not as strongly restricted to the forest canopy (Figure D.1.b). Because of its rarity, much less is known about this species. For example, of approximately 10,000 individual small mammals and amphibians trapped with pitfall traps in the Oregon Coast Range, only 60 were white-footed voles (Gomez 1992). He found this species to be more abundant in deciduous forests than elsewhere, and it was associated with riparian areas where deciduous vegetation was more abundant. Voth et al. (1983) suggested that the species' diet is restricted to foliage of deciduous plants.

A second important food web in coniferous forests in the Pacific Northwest involves fungivores. Although a number of species eat fungi, the western red-backed vole and the northern flying squirrel are most notable within this group. The northern flying squirrel is the primary prey species for the northern spotted owl in Washington and most of Oregon. The red-backed vole is among the top five prey species (Forsman et al. 1984, Thomas et al. 1990) and is endemic to the Pacific Northwest (Figure D.5.a). Old-growth forests are optimal habitat for the flying squirrel and the red-backed vole. The red-backed vole spends most of its time in underground burrows and feeds on the fruiting bodies of hypogeous fungi (Maser et al. 1978a). Many mammals consume fungi, but few depend on this food source to the extent that the red-backed vole does. Gashwiler (1959, 1970) and Goertz (1964) reported a decrease or elimination of this species following clear-cutting. The decrease is believed to have resulted from the disappearance of hypogeous fungi after this form of

timber harvest (Maser et al. 1978b). Hypogeous fungi form symbiotic relationships with the roots of coniferous trees, and these associations are important to the overall health of the trees. The northern flying squirrel also consumes fungi (McKeever 1960, Maser et al. 1978b), at least seasonally, although it spends most of its time in the forest canopy. The flying squirrel also eats epiphytic lichens that are abundant in the forest canopy. The northern flying squirrel, red tree vole, and red-backed vole comprise more than 75 percent of the diet of the spotted owl in the Oregon Cascades, so their dependence on the production of fir needles, fungi, and lichens in coniferous forest is important to these food webs and the owl.

Spotted Owl Prey[2]

The availability of energy for maintenance and reproduction is important to all organisms, so to properly manage an animal, the ecology of its food sources must be considered. Although dietary requirements of a predator may be met by a large range of sources, many species, and the spotted owl in particular, are selective in the prey they feed upon. Although a variety of species are eaten by the owl, only a few species make up the majority of the owl's diet within a given region. More than 90 percent of the spotted owl prey consists of mammals (Forsman et al. 1984). Spotted owl diets and the habitat associations of its prey were reviewed thoroughly by Thomas et al. (1990:201). This section summarizes their report and adds recently published information that augments their work.

The diet of northern spotted owls varies regionally, but within a region it is typically dominated by two or three species (Thomas et al. 1990). Composition of diets varies seasonally (Forsman et al. 1984) but appears to be stable over time based on studies during different years (Thomas et al. 1990). Flying squirrels (*Glaucomys sabrinus*) and woodrats (*Neotoma cinerea* and *N. fuscipes*) dominate the diet in mesic and dry forests, respectively (Thomas et al. 1990). Snowshoe hares (*Lepus americanus*) and brush rabbits (*Sylvilagus bachmani*) typically represent less than 10 percent of the prey based on number of prey taken, but because of their larger size, they have been reported to comprise up to 25 percent of the prey biomass (Forsman et al. 1984:43). Red tree voles (*Phenacomys longicaudus P. pomo*) and deer mice (*Peromyscus maniculatus*) may constitute more than 30 percent of prey numbers and more than 10 percent of prey biomass regionally (Thomas et al. 1990). Western red-backed voles (*Clethrionomys californicus*) usually comprise a smaller percent of the diet than do red tree voles and deer mice, generally less than 5 percent of prey biomass (Forsman et al. 1984:41).

Northern Flying Squirrels.—Northern flying squirrels have a broad distribution throughout coniferous forests and are found in western Washington, Oregon, and northern California (Figure D.5.a). Flying squirrels are arboreal mammals and are not resident in recent clear-cuts. They nest in many substrates, including cavities in live and dead trees. Density does not appear to be strongly dependent on stand age alone. In the Oregon Coast Range, flying squirrels were more abundant in old-growth than in second-growth stands during some, but not all, years of a study by Carey et al. (1992). Similar densities were reported in old-growth and second-growth stands in the Oregon Cascades (Rosenberg and Anthony 1992). In an ongoing study in true fir (*Abies* spp.) forests in Lassen National Forest (north-central California), preliminary data suggest squirrel densities are markedly lower in an intensively managed shelterwood cut than in young- and old-growth stands (J. Waters, U.S. Forest Service, Arcata, California, pers. comm.).

[2]Contributed by Daniel Rosenberg, Redwood Sciences Laboratory, U.S. Forest Service, Arcata, California

Woodrats.—The dusky-footed woodrat (*N. fuscipes*) is limited in distribution to parts of western Oregon and most of western California (Figure D.5.b), while the bushy-tailed woodrat (*N. cinerea*) is found throughout Washington and Oregon, and in parts of northern California (Figure D.5.c). Woodrats are associated with seral stages that have abundant understory vegetation and coarse woody debris, such as early successional stages (recent clear-cuts) and older seral stages (Thomas et al. 1990); bushy-tailed woodrats also are associated with rocky areas, such as talus slopes (Thomas et al. 1990).

Deer mice.—The deer mouse (*Peromyscus maniculatus*) is one of the most widely distributed mammal species in North America and is found throughout Oregon, Washington, and California. Such a wide-ranging species would be expected to be a habitat generalist, and data from the Pacific Northwest support this contention. Deer mice do not show consistent preferences for particular stand ages (Thomas et al. 1990). The forest deer mouse (*P. oreas*) inhabits older forests in western Washington and southern British Columbia (Figure D.5.c). Because of its extensive use of tree canopies, it is probably an important prey species for owls in Washington (West 1991).

Red tree vole.—The red tree voles (*Phenacomys* ssp.) have the most restricted distribution of all the species preyed upon by spotted owls. Before the California population (*P. pomo*) was recognized to be a species separate from the Oregon (*P. longicaudus*) species (Johnson and George 1991), the range of the red tree vole included parts of western Oregon and northwest California (Figure D.2). The California population now is considered a separate species based on morphometric and genetic data. Habitat associations of these species are based on relatively small sample sizes, but there is a trend of greater relative abundance with increasing stand age, with the highest densities in old-growth forests (Corn and Bury 1991, Ruggiero et al. 1991b).

Rabbits and Hares.—Brush rabbits occur in most of western Oregon and California, and appear to be absent from Washington (Figure D.5.f). Snowshoe hares are found in western Oregon and Washington, and into north-central California (Figure D.5.e). No research has been conducted to specifically study habitat associations of lagomorphs in relationship to spotted owl habitat. In general, these species occupy brushy, densely vegetated habitats (Thomas et al. 1990) and are not more abundant in older forests. It is primarily young of the year that are preyed upon by spotted owls (Forsman et al. 1984:41), so dispersal habitat may be most important when considering these species as spotted owl prey.

Red-backed voles.—Western red-backed voles occur throughout western Oregon and northwest California, and the southern red-backed vole (*C. gapperi*) occurs in western Washington (Figure D.5.f). Western red-backed voles live in a variety of forested habitats, but densities are low in recently burned clear-cuts and their occurrence may be positively associated with woody debris (reviewed by Alexander and Verts, In press). No differences in abundance of *Cleithrionomys* spp. were found in unmanaged young (30 to 70 years) Douglas-fir stands compared to older seral stages (Corn and Bury 1991, Gilbert and Allwine 1991, West 1991), but abundance was much lower in managed young stands than in old-growth stands (Rosenberg and Anthony 1990).

Managing prey for the northern spotted owl.—Recent research on prey species was motivated, in part, by an interest in increasing prey abundance through silvicultural prescriptions. The results to date do not show consistent patterns that would allow this to be achieved. This, combined with the difficulty in assessing the relationship between prey abundance and availability, makes the feasibility of manipulating prey densities to increase owl use of

forests questionable. Experimental manipulations of habitat and assessments of prey response (as well as owl response) are needed to test the effectiveness of management techniques. Failure of habitat models to predict animal response in locations and years other than the ones from which the data originally were collected is a common problem (Noon 1986). This probably results from the numerous factors besides habitat that affect animal populations (Noon 1986). The ability to manipulate habitat to increase prey availability is difficult because of the complex interaction of predator and prey.

Ecology of Riparian Ecosystems and Native Fishes

The committee's list includes approximately 132 species of animals that are federally listed as threatened or endangered, candidates for federal listing, species of special concern, or older-forest associates and are associated with riparian areas. This list of species is diverse and includes three birds, four mammals, 12 amphibians, 45 molluscs, and 34 arthropods as well as 28 fish. Riparian associates comprise approximately one third of the other species considered as a result of Secretary of the Interior Lujan's request. The association to riparian areas by these species indicates the importance of riparian areas in the recovery plan for the spotted owl.

Riparian ecosystems represent a small proportion of the land base (generally less than 5 percent), but they provide habitat for a rich and diverse group of plants and animals. A large number of fish stocks has been identified as being at risk (Nehlsen et al. 1991, Moyle et al. 1989, Williams et al. 1989), in part because of intensive timber harvest along streams in many areas (see section on Native Fishes). The importance of riparian ecosystems, their roles in coniferous forests, and their potential importance as ecological corridors among DCAs is discussed next.

Riparian Ecosystems

Recently ecologists and land managers have recognized the importance of structure and function of riparian zones for terrestrial and aquatic ecosystems (Gregory et al. 1988, Knight and Bottorf 1984, Meehan et al. 1977, Beschta 1989). These functions include stream shading, bank stabilization, nutrient uptake, input of leaves and needles into streams, sediment filtering, bank building, and the contribution of large wood (Elmore and Beschta 1987, Gregory et al. 1988). The contrast in communities and physical environment creates rich patterns of processes and structure that are the basis for the high biotic diversity found in riparian zones (Gregory et al. 1988).

Management.—The segregation of riparian areas from other ecosystems by state and federal agencies is a common management approach. The result predominately has been the development of federal policies and state forest practices that allow varying intensities of forest activities. The states of California, Washington, and Oregon have addressed riparian ecosystems in their forest practices rules. The states also are involved in an extensive monitoring program to evaluate the effectiveness of these rules.

In general, federal agencies are consistent in their approach to the classification of streams. Streams are segregated into four classes based on the presence or absence of fishes, the uses of the water (e.g., domestic use by cities, recreation), and whether the stream is a significant contributor to a higher-class stream. The states use predominately the same process but have delineated their streams by consolidating the categories into as few as two or as many as four classes. Timber harvest regulations, however, vary among states

and are less restrictive under state forest practices laws than under federal management guidances. Regulations in the states range from retention of as few as 21 conifers per 1,000 feet of stream in one state to 50 trees in another. None of the three states' laws addresses full floodplain function.

Not all riparian policies address small upper watershed tributaries, full floodplain function, and small wetland areas within the terrestrial forest matrix. The result is a landscape with various widths of protection along stream systems that allow varying degrees of harvest. This buffer strip concept appears to be inherently unstable, biologically and physically (Gregory et al. 1988). Changes in natural patterns and composition of streamside vegetation have major short- and long-term consequences to channel characteristics and morphology, streambed and channel stability, ecosystem functioning, wildlife habitat, and the biological productivity of streams and wetlands (Beschta 1989).

Riparian areas and wetlands provide some of the most important wildlife habitat in the forest lands of the western states. Their use as habitat generally is greater than that of surrounding areas because the major life requirements for many species are present (Oakley et al. 1985). They are used for foraging and watering, breeding and rearing, hiding and resting, and thermal cover. Of the 414 wildlife species in Oregon and Washington, 359 (87 percent) use riparian zones or wetlands during some season(s) or part(s) of their life cycle. Of these, 318 species use one or more of the plant communities directly associated with riparian zones and wetlands (Oakley et al. 1985). Use is similar in California. Riparian areas support a diverse arthropod fauna, and many of these species are important food items for vertebrate animals (J. Latlin, Oregon State University, pers. comm.). In addition to wildlife species directly dependent on riparian areas, populations in adjacent areas are influenced strongly by the riparian community (Stevens et al. 1977). Management aimed at maintenance or protection of riparian zones is extremely important because of the many species that use these areas (Carothers 1977).

Riparian areas are more common than wetlands in the forested systems of the west. Oakley et al. (1985) identified six major reasons that riparian and wetland areas are important for wildlife:

1. They contain the three critical habitat components: food, cover, and water.

2. They contain a greater diversity of plant species and vegetative structure than adjacent uplands.

3. The elongated shape of most riparian zones maximizes edge effect with the surrounding forest as well as with water.

4. They have different microclimates from surrounding coniferous forests due to increased humidity, a higher rate of transpiration, and greater air movement.

5. They serve as natural migration routes and travel corridors.

6. They play a major role in maintaining water quality and quantity.

Riparian and wetland areas also are important for many other types of land uses. Highly productive timber sites frequently occur along or around these areas. Recreation, road locations, mining activities, road building material, and home sites also are among the many other important uses. For these reasons and many others, riparian and wetland areas are recognized as critical areas in multiple-use management and planning.

Summary.— Employment of an ecosystem perspective in developing policy and management guidance allows for an assessment of riparian function, structure, and interaction with adjoining ecosystems. This process will provide self-sustaining streamside forests that will ensure the desired conditions of riparian resources for the future (Gregory and Ashkenas 1990). A single prescription for riparian management will not address the variation in riparian resources that occur throughout the region's forests (Gregory and Ashkenas 1990). For example, areas within the range of the northern spotted owl east of the Cascade range in Oregon require different considerations than do coastal areas. Landscape and basin considerations should be considered prior to the development of site-specific prescriptions for riparian management.

The committee identified the following as appropriate management considerations in riparian areas:

- *Recognize the unique value of riparian areas within the context of the environment in which they are located.*

- *Consider landscape connectivity.*

- *Consider full floodplain function.*

- *Recognize the importance of all stream systems, regardless of size, and view these streams and their associated riparian areas from a basin (landscape) perspective.*

- *Maintain species and age-class distributions of streamside vegetation that will provide large woody debris to the forest floor and stream channel.*

- *Restore natural processes within the stream channel and the riparian management zone.*

- *Monitor restoration activities to determine if desired results are achieved.*

Native Fishes

Twenty-eight species comprising approximately 1,181 native fish stocks occur in approximately 455 streams, rivers, lakes, and estuaries within the range of the northern spotted owl. Of these, there are 348 streams with stocks at risk, and the number of stocks that are considered at risk totals 766. Any of these fish stocks potentially could benefit from the recovery plan for the owl (Table D.4). Throughout the owl's range, most aquatic habitat has been impacted in some way by land-use activities. Restoration of depleted stocks (the stock concept is discussed below) and protection of currently secure stocks depends on suitable habitat for all life stages of those stocks.

This inventory of species and stocks is not complete, owing to the extensive range encompassed in this survey and the scarcity of information on species other than those of particular commercial or sporting interest. Little genetic identification of fish stocks has been done in the region; therefore distinct stocks may have been overlooked. In general, there are two major life history patterns among fishes in these areas, anadromous (spawning in fresh water and maturing in salt water) and resident (remaining in fresh water). Salmonids make up a major portion of the stocks identified within the range of the northern spotted owl. Information on distribution, stock size, and habitat requirements generally are available for these species because of their economic importance and recreational value.

Stock concept.—The term "stock" was adopted 51 years ago, shortly after the first attempts to describe stocks of Pacific salmon and discuss their importance to management of the species (McIntyre 1983). After reviewing the results of early marking experiments, Rich (1939) concluded that Pacific salmon were divided into many local populations or what we now refer to as stocks (Ricker 1972). Anadromous salmonid species comprise populations that originate from specific watersheds as juveniles and generally return to their natal streams to spawn. This life cycle results in a large degree of reproductive isolation of interbreeding individuals or stocks (Ricker 1972). Stocks represent unique genetic entities, and loss of a stock is irreversible. It is at the stock level that conservation and management of salmon is taking place. Additional documentation and discussion of fish stocks can be found in Nehlsen et al. (1991).

Effects of land-use activities on fishes and fish habitat.—The condition of watersheds dictates the physical and chemical makeup of the streams that drain them and of the lakes that lie within them (Meehan 1991). Vannote et al. (1980) proposed a "river continuum concept" based on a continuous gradient in physical variables within a river system from headwaters to mouth. This gradient leads to a continuum of biotic adjustments and consistent patterns of loading, transport, utilization, and storage of organic matter along the length of a river (Vannote et al. 1980). Management of fish habitat, and therefore fish populations, requires consideration of the habitat within the watershed to accommodate stream and terrestrial processes that work in concert throughout the basin.

Gradients within the "river continuum" also provide a basis for assessing cumulative effects. For example, fine sediment is transported from high gradient to low gradient areas, where it can accumulate to levels that affect fisheries. The translocation downstream and the contribution from several sources make traditional cause-and-effect evaluation of cumulative effects difficult, if not impossible. Multiple ownerships complicate the issue and may impede evaluation of upstream effects.

Many land-use activities can affect aquatic habitat and fish populations. Such activities include road construction, timber harvest, livestock grazing, hydroelectric development, chemical applications, mining, and recreation. The effects of road construction and timber harvest, which are significant within the range of the spotted owl, are discussed here.

Roads.—Roads can modify natural drainage systems and accelerate erosion processes; these changes can alter physical processes in streams, leading to changes in streamflow regimes, channel configuration, sediment transport and storage, substrate composition, and stability of slopes adjacent to streams (Furniss et al. 1991). Increased sediment input from roads can affect fish habitat. The principle source of sediment entering streams is by mass soil movements and surface erosion processes (Swanston 1991), although forest roads can substantially increase the frequency of mass soil movements in steep watersheds (Everest et al. 1987). Furniss et al. (1991:297-323) found that rarely can roads be constructed without some effect on fish habitat. However, roads that have been properly planned, constructed, and maintained have minimized these effects. Regular maintenance of roads to reduce impacts on fish habitat should be practiced on all roads, not just those that are actively used.

Timber harvest.—Effects of timber harvest and silvicultural treatments (planting, thinning, burning, mechanical site preparation, and application of chemicals) on stream ecosystems are complex (Meehan 1991). Various timber-harvest strategies ranging from clear-cutting to long-rotation selective harvest,

affect fish habitat in different ways. In general, the effects of timber harvesting on fish habitat include increased sedimentation and water temperatures, changes in seasonal flow patterns, quantity and distribution of woody debris, and channel morphology (Chamberlin et al. 1991:181-205).

Quantity and timing of sediment entry into stream systems are important in determining habitat quality for fishes. Specific substrate conditions are required for spawning, rearing, and over-wintering. Increases in fine sediment from logging activities has been shown to decrease survival of salmonid fry (Scriver and Brownlee 1989). Substrate conditions also are important for salamanders, aquatic insects and aquatic plants that contribute to energy processing in aquatic environments.

When streamside trees are removed, increased light may stimulate primary production (Murphy and Meehan 1991). Increased periphyton (algae and associated microorganisms growing attached to any submerged surface) production after canopy removal may increase the abundance of invertebrates and fishes, mainly by increasing the quantity of detritus (Murphy and Meehan 1991). Increased primary production from canopy removal may last for a short period of time and then diminish due to canopy closure, which is often denser in even-age, second-growth forests than in older forests (Murphy and Meehan 1991). In addition, cumulative downstream effects of increased water temperature may create downstream areas that are not suitable for native fishes.

Among the most important long-term effects of forest management activities on fish habitat in western North America have been changes in distribution and abundance of large woody debris (more than 14 inches in diameter) in streams (Hicks et al. 1991). Large woody debris plays a critical role in controlling stream channel morphology, regulating the movement and storage of inorganic and organic material, and in creating and maintaining fish habitat (Hicks et al. 1991). Debris removal was common in the 1960s and 1970s and often was encouraged by fisheries biologists to improve fish access to upstream areas. Since then, the importance of woody debris in stream channel form and function has been recognized. Removal of large woody debris from stream channels has been shown to affect fish populations adversely. Debris removal can cause a decline in channel stability and a corresponding reduction in the quality and quantity of pools and cover (Hicks et al. 1991).

Removal of large trees from riparian zones has caused long-term reduction in the recruitment of large woody debris to stream channels, leading to a reduction in the quality of fish habitat (Hicks et al. 1991). Murphy and Koski (1989) modeled the depletion and input of large woody debris from second-growth forests. Their model indicated that 90 years later, clear-cut logging without a buffer strip would reduce large woody debris by 70 percent, and recovery to prelogging levels would take more than 250 years.

The use of buffer strips has been shown to reduce the localized effects of streamside timber harvest. Murphy et al. (1986) found that streams with buffer strips did not consistently differ from old-growth streams; streams in clear-cuts without buffer strips had more periphyton, lower channel stability, and less canopy, pool volume, large woody debris, and undercut banks than streams in old-growth forests.

Summary.—Twenty-eight species comprising over 1,181 fish stocks were identified within the range of the northern spotted owl. A total of 766 stocks (Table D.10) are 1) listed federally as threatened or endangered, 2) candidates for federal listing, 3) species of special concern (state), or 4) are considered at risk by Nehlsen et al. (1991), Moyle et al. (1989), or Williams et al. (1989). These stocks occur in 348 streams throughout the Pacific Northwest (Tables

Table D.10. List of fish stocks of various species and the number of stocks at risk.

Species/Stock	California Number of Stocks Total	California Number of Stocks At Risk	Oregon Number of Stocks Total	Oregon Number of Stocks At Risk	Washington Number of Stocks Total	Washington Number of Stocks At Risk
Bigeye marbled sculpin	1	1				
Bull trout	1	1	31	31	13	
Chum salmon	8		41	41	35	19
Clear Lake hitch	1	1				
Coho salmon	45	45	114	114	33	13
Fall chinook salmon	51	15	54	54	22	21
Gualala roach	1	1				
Jenny Creek sucker	1	1	1	1		
Klamath River lamprey	5	5				
Millicoma dace			3	3		
Navarro roach	2	2				
Nooky (Chehalis) dace					33	33
Olympic mudminnow					13	13
Pink salmon	4	4			8	3
Pit roach	1	1				
Redband trout	7	7	5	5		
Reticulate sculpin	2	2				
Rough sculpin	1	1				
Russian River tule perch	1	1				
Sacramento splittail	2	2				
Sacramento winter chinook salmon	1	1				
Salish sucker					18	18
Sea-run cutthroat trout	21	21	88	52	72	24
Sockeye salmon	0	EXTINCT	2	1	8	2
Spring chinook salmon	16	16	40	13	32	10
Summer chinook salmon			1	1	4	2
Summer steelhead trout	33	33	38	8	35	14
Tidewater goby	14	14				
Tomales roach	1	1				
Umpqua chub			3	3		
Willamette chub			6	6		
Winter steelhead trout	68	2	101	53	39	30
Total	**288**	**178**	**528**	**386**	**365**	**202**

Table D.11. California streams (or stream reaches) identified as containing at least one fish stock that is considered to be at risk.

Basin	Stream	Steelhead Trout Sum	Steelhead Trout Win	Salmon Chinook Spr	Salmon Chinook Sum	Salmon Chinook Fall	Salmon Coho	Sea-run Cutthroat Trout	Other[a]	References[b]
Albion	Albion River						X		16X	2,7
Russian	Austin Creekl		P				X			3
Klamath	Beaver Creek		P			P	X		7X	1,3,4,5
Big	Big River		P				X		16X	2,3,7
Klamath	Blue Creek	X	P			P	X	X		1,3,4
Klamath	Bluff Creek	X	P			P	X			1,3,4
Klamath	Bogus Creek		P			P	X			1,3
Klamath	Boise Creek	X					X			4
Sacramento	Bull Creek								11X	3,7
Klamath	Camp Creek	X	P			P				1,3
Klamath	Canyon Creek	X	P	X		P				3,4,5
Klamath	Clear Creek	X	P	X		P				4
Clear Lake	Clear Lake								4X	5
Klamath	Dillon Creek	X	P			P				4
Klamath	E.ast Fork Indian Creek	X	P			P				3
Eel	Eel River	X				X	X	X	3P,16X	2,5,6,7
Klamath	Elk Creek	X	P			P				4
Humboldt	Elk River					X	X	X		1,6,7
Rogue	Elliot Creek								12X	5
Humboldt	Freshwater Creek					X	X	X		3,6,7
Garcia	Garcia River		P				X		9X,16X	2,3,5,7
Klamath	Grider Creek		P			P	X			3
Gulala	Gulala River		P				X		5X,16X	2,3,5,7
Klamath	Hayfork Creek	X	P							3
Klamath	Horse Linto Creek	X	P			P	X	X		1,3,4
Smith	Hurdygurdy Creek		P			P		X		3
Klamath	Indian Creek	X	P			P				3,4,5
Humboldt	Jacoby Creek					X	X	X		3,6,7
Smith	Jones Creek		P			P		X		3
Klamath	Kidder Creek		P						7X	3,5
Klamath	Klamath River	X		X			X	X		2,6
Redwood	Lacks Creek		P				X			3
Laqunitas	Laqunitas Creek		P				X			3
Humboldt	Little River					X		X		6,7
Little	Little River		P				X			3
Klamath	Little Shasta River								7X	5
Klamath	Lower Klamath River	X		X		P	X	X	3P,9X	2,5,6,7,
Klamath	Lower Klamath Tributaries					X				6,7
Mad	Mad River	X				X	X	X	3P,9X,16X	2,5,6,7
Humboldt	Maple Creek					X		X		6,7
Mattole	Mattole River		P			X	X		3P,16X	
Sacramento	McCloud River								2X,11X	3,4
Humboldt	McDonald Creek		P			X		X		1,6,7,
Rogue	Middle Fork Applegate River								12X	5
Eel	Middle Fork Eel River	X	P							4,5,6
Smith	Middle Fork Smith River			X						6
Klamath	Mill Creek	X	P				X			3,4
Smith	Mill Creek		P			P	X	X		3
Smith	N. Fork Smith River			X						6
Klamath	N. Fork Trinity River	X	P	X		P				4,5,6
Napa	Napa River		X						15X	5,6
Navarro	Navarro River		P				X		8X,16X	2,3,5,7
Klamath	New River	X	P	X		P	X			3,4,5,6
Noyo	Noyo River		P				X		16X	2,3,7
Laqunitas	Olema Creek		P				X			3
Sacramento	Pit River								1X,10X,13X	2,3,5,7
Redwood	Prairie Creek		P			P	X	X		3,6
Sacramento	Racoon Creek								11X	3,7

continues—

continued—

Basin	Stream	Steelhead Trout Sum	Steelhead Trout Win	Salmon Chinook Spr	Salmon Chinook Sum	Salmon Chinook Fall	Salmon Coho	Sea-run Cutthroat Trout	Other[a]	References[b]
Klamath	Red Cap Creek	X				P	X			4,5
Redwood	Redwood Creek	X	P			X	X	X	3P,16X	2,3,5,6,7
Smith	Rowdy Creek		P			P	X	X		3,6
Klamath	Rush Creek		P			P	X			3
Russian Gulch	Russian Gulch Creek		P				X			3
Russian	Russian River		P			X	X		3P,8X,9X, 14X,16X	2,3,5,6,7
Smith	S. Fork Smith River	X	P	X		P	X	X		1,3,6
Klamath	S. Fork Trinity River	X	P	X		P				3,4,5,6
Salmon	Salmon Creek						X		16X	2,7
Klamath	Salmon River	X	P	X		P				3,4,5
Klamath	Scott River	X				X				1,6
Klamath	Seiad Creek		P			P	X			3
Klamath	Shasta River					X			7X	5,6,7
Klamath	Small Tributaries to Hayfork Creek		P				X			3
Smith	Smith River	X	P	X		X	X	X	3P,16X	2,3,4,6,7
Sacramento	Tate Creek								11X	3,7
Klamath	Tish Tang Creek	X	P			P	X			3,4
Klamath	Trinity River	X		X				X		2
Klamath	Ukonom Creek	X	P			P				3
Klamath	Upper Klamath River	X		X		P	X		6X,7X	2,5,6
Sacramento	Upper McCloud River								11X	3,7
Eel	Upper S. Fork Eel River		P				X			3
Sacramento	Upper Sacramento River		X	X					3P,11X,15X, 18X	2,5,6,7
Eel	Van Duzen River	X								5,6
Walker	Walker Creek		P				X		16X,17X	2,3,5,7
Sacramento	Whisky Creek								11X	3,7
Klamath	Wooley Creek	X		X		P				4,5,6

X = endangered, threatened, candidate, or species of concern on federal or state list or identified at risk by Moyle et al. (1989), Nehlsen et al. (1991), or Williams et al. (1989).
P = stock is present in stream.
Spr = Spring
Sum = Summer
Win = Winter

[a] ***Other species:*** 1) bigeye marbled sculpin, 2) bull trout, 3) chum salmon, 4) Clear Lake hitch, 5) Gualala roach, 6) Jenny Creek sucker, 7) Klamath River lamprey, 8) Navarro roach, 9) pink salmon, 10) Pit roach, 11) redband trout, 12) reticulate sculpin, 13) rough sculpin, 14) Russian River tule perch, 15) Sacramento splittail, 16) tidewater goby, 17) Tomales roach, 18) Sacramento River winter chinook salmon.

[b] ***References:*** 1) California Department of Fish and Game. 1991 Comments to 26 November 1991 draft of Appendix D. See administrative record. 2) Frissell (1991), 3) Gerstung (1991). California Department of Fish and Game. Correspondence and transcripts of Other Species and Ecosystem Issues in Recovery Planning for the Northern Spotted Owl: technical workshop. Volume 1, August 8, 1991. Portland, Oregon. See administrative record. 4) Johnson et al. (1991); 5) Moyle et al. (1989). 6) Nehlsen et al. (1991). 7) Williams et al. (1989).

Table D.12. Oregon streams (or stream reaches) identified as containing at least one fish stock that is considered to be at risk.

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	References[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Alsea	Alsea River		X	X			X	X	2X	1,3
Alsea	Alsea estuary						X	X		3,4
McKenzie R.	Anderson Creek			P					1X	2
Deschutes	Badger Creek								5X	2
Columbia	Bear Creek		X			X				3
Columbia	Beaver Creek		X				X			3
Mid. Coast	Beaver Creek						X			3
Rogue	Beaver Creek	P	P				X			2
Umpqua	Big Bend Creek	P		P			X			4
Columbia	Big Creek		X			X	X	X	2X	1,3
Mid. Coast	Big Creek		X				X	X		2,3,4
Rogue	Billings Creek					X				3
Santiam	Boulder Creek								1X	2
Nestucca	Boulder Creek		X				X	P		2,3,4
Umpqua	Boulder Creek	P	P	P			X	X		2,4
Willamette	Calapooia River		X							3
Umpqua	Calf Creek	P	P	P			X	X		2
Deschutes	Candle Creek								1X	4
Rogue	Canyon Creek		P			X				4
Mid Coast	Cape Creek		X				X	X	2X	3,4
Illinois	Cave Creek		P			X				2
Columbia	Chenowth Creek		X				X			3
Klamath	Cherry Creek								1X	2
South Coast	Chetco		P			X	X	X	2X	1,3,4
Willamette	Clackamas River	P	X	X			X	X	1X	1,2,3
Columbia	Clatskanie River		X			X	X			3
North Coast	Coal Creek		P				X	P	2X	4
Willamette	Collawash/Hot Springs Fork			P			X			2
Rogue	Collier Creek					X				3
South Coast	Coos River					X	X	X	2X	1,3
Umpqua	Copeland Creek	P	P	P			X	X		2,4
Coquille	Coquille River			X			X	X	2X	1,3
Deschutes	Crooked River								1X	4
Mid. Coast	Cummins Creek		X				X	X	2X	2,3,4
McKenzie R.	Deer Creek			P					1X	2
Salmon	Deer Creek						X	P		4
Deschutes	Deschutes River								1X,6X	1,2,3,4
Alsea	Drift Creek		X	X		X	X	P		2,3,4
Siletz	Drift Creek	X	X	X		X	X	P		2,3
Sixes	Dry Creek					X	X	P	2X	2,4
Columbia	Eagle Creek	X	X	P			X			2,3
Nehalem	East Fork Foley Creek							P	2X	4
Rogue	East Fork Illinois River		X			X	X	P		3,4
Winchuck	East Fork Winchuck River		P			X	X	P		4
South Coast	Elk River		P			X	X	X	2X	1,2,3,4
South Coast	Emily Creek		P			X	X	X		2,3,4
South Coast	Euchre Creek					X	X	X	2X	1,3
Klamath	Evening Creek								1X	2
Willamette	Fern Creek Shady Del								8X	2
Columbia	Fifteen Mile Creek	P	X							2,3
Willamette	Fish Creek	P	P	P			X			2
South Coast	Floras Creek						X	X	2X	1,3
Alsea	Flynn Creek						X	P		4
Rogue	Foster Creek					X				3
Umpqua	Franklin Creek		P				X	X		2,4
Willamette	French Pete Creek								1X	4
Columbia	Gnat Creek		X			X	X			3
Willamette	Gray								8X	4
Rogue	Grayback Creek		P			X	X			2
Siuslaw	Greenleaf Creek		P				X			4
Columbia	Herman Creek	X	X				X			3

continues—

continued—

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	References[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Hood	Hood River	X	X	X		X	X	X	1X	1,3
Willamette	Horse Creek								1X	
Rogue	Horse Sign Creek					X				3
South Coast	Hunter Creek					X				3
Rogue	Illinois River		X			X	X	P		1,3,4
Rogue	Indigo Creek		X			X		P		2,3
Deschutes	Jack Creek								1X	4
S. Umpqua	Jackson Creek		P	P			X	P		4
Klamath	Jenny Creek								3X	4
Rogue	Jim Hunt Creek					X				3
Deschutes	Jordon Creek								5X	2
North Coast	Kilchis River		X				X	X	2X	1,3
McKenzie R.	Kink Creek			P					1X	2
Columbia	Klaskanine River		X			X	X		2X	3
Rogue	Lawson Creek		X			X	X	P		2,3,4
Columbia	Lewis and Clark River		X			X	X	X	2X	1,3
Nestucca	Limestone Creek		X				X	P		2,3,4
Columbia	Lindsey Creek						X			3
Rogue	Little Applegate River	P					X			2
Wilson	Little N. Fork Wilson River						X	P		4
Rogue	Lobster Creek					X				3
Willamette	Lost Creek Scott Creek								1X	2
Rogue	Lower Rogue River	X				X	X	X	2X	1,3
Umpqua	Lower Umpqua River						X	X	2X,7X	1,3
Deschutes	Marsh Creek								1X	2
Willamette	McKenzie River		P	X					1X,8X	1,2,3,4
Deschutes	Metolius River			P					1X,6P	1,2,4
Miami	Miami River		P				X	X	2X	1,3
Willamette	Lower Willamette River			X		X			8X	1,3
Hood	Middle Fork Hood River	P	P				X		1X	4
Willamette	Middle Fork Willamette River								1X,8X	1,4
Columbia	Mill Creek		X				X			3
Coos	Millicoma River								4X	4
Columbia	Milton Creek		X				X			3
Willamette	Molalla River		X							3
Columbia	Mosier Creek		X				X			3
Necanicum	Necanicum River						X	X	2X	1,3
Nehalem	Nehalem River				X		X	X	2X	1,3,4
Nestucca	Nestucca River		X				X	X	2X	1,3,4
North Coast	Netarts Bay								2X	3
Nestucca	Niagara Creek		X				X	P		2,3,4
Rogue	N. Fork Lobster Creek					X	X	P		4
Trask	N. Fork N. Fork Trask River						X	P		4
Siletz	N. Fork Siletz River			P			X	P		4
Umpqua	N. Fork Smith River		P			X	X	X		2
Trask	N. Fork Trask						X	P		4
Umpqua	N. Umpqua River	P	P	P		X	X	X	7X	1,2,3,4
Willamette	Oak Grove	P	P	P			X			2
Deschutes	Odell Creek								1X	2
McKenzie R.	Olallie Creek			P					1X	2
Rogue	Palmer Creek	P	P				X			2
South Coast	Pistol River					X	X	X	2X	1,3
Columbia	Plympton Creek					X				3
Nestucca	Powder Creek		X				X	P		2,3,4
Willamette	Pudding River		X							3
Rogue	Quosatana Creek	P	P			X		P		2,3
Deschutes	Roaring Creek								1X	4
Willamette	Roaring River		P	P			X		1X	2,4
Mid Coast	Rock Creek		X				X	X	2X	2,3,4
N. Coast	Rock Creek						X	X		3,4
Deschutes	Rock Creek								5X	2

continues—

continued—

Basin	Stream	Steelhead Trout Sum	Steelhead Trout Win	Salmon Chinook Spr	Salmon Chinook Sum	Salmon Chinook Fall	Salmon Coho	Sea-run Cutthroat Trout	Other[a]	References[b]
Columbia	Rock Creek		X							3
Rogue	Rogue River			P		X	X	P		4
Rogue	Rough and Ready Creek		P				X	P		4
Coos	South Coos River								4X	4
Coquille	South Fork Coquille River	P	P	P		X	X	P		2
Willamette	South Fork McKenzie River	P		P					1X	2,4
Umpqua	South Umpqua River	P	P	X			X	P	7X	1,2,3,4
Mid Coast	Salmon River		X				X	X	2X	1,3
Sandy	Salmon River	P	P	P			X			2,4
Salmon	Salmon estuary					X	X	X		3,4
Nehalem	Salmonberry River		P			X		P		4
Sandy	Sandy River	P		X		X	X	X		1,3
Willamette	Santiam River		X	X					1X,8X	1,3
Columbia	Scappose Creek		X				X		2X	3
Yachats	School Fork						X	P		4
Klamath	Seven Mile Creek								1X	2
Rogue	Shasta Costa Creek	X	P			X	X	P		2,3,4
Siletz	Siletz River	X	X	X		X	X	X	2X	1,3,4
Rogue	Silver Creek		X			X		P		2,3
Siuslaw	Siuslaw River		P				X	X	2X	1,3
Sixes	Sixes River						X	X	2X	1,3
Sixes	Sixes estuary						X	X	2X	3,4
Umpqua	Steamboat Creek	P	P	P			X	X		2,4
Klamath	Sun Creek								1X	4
Siuslaw	Sweet Creek		P			X	X	X		2
McKenzie R	Sweetwater Creek			P					1X	2
Columbia	Tanner Creek		X						2X	3
South Coast	Taylor Creek						X			2
Mid Coast	Tenmile Creek		X				X	X	2X	2,3,4
Columbia	Three Mile Creek		X							3
Nestucca	Three Rivers		X			X	X	P		2,3
Tillamook	Tillamook Bay		X				X		2X	3
Tillamook	Tillamook River		X				X	X	2X	1,3
Coos	Tioga Creek								4X	4
Nestucca	Tony Creek		X				X	P		2,3,4
Deschutes	Trapper Creek								1X	4
Trask	Trask River						X	X	2X	1,3
Deschutes	Tygh Creek								5X	2
Rogue	Upper E. Fork Illinois River		P			X	X			2
Mid. Coast	Upper Knowles		P				X			4
Hood	Upper Middle Fork Hood River	P	P				X		1X	4
Rogue	Upper Rogue River	X					X	P		1,3,4
Umpqua	Upper S. Umpqua River			X			X	P		3,4
Columbia	Viento Creek						X			3
Umpqua	Wassen Creek		P				X	X		2
Hood	W. Fork Hood River	P					X	X		2
Deschutes	White River								5X	2
Wilson	Wilson River		X				X	X	2X	1,3
South Coast	Winchuck River		P			X	X	X	2X	1,2,3
South Coast	Winchuck estuary					X	X	X		3,4
Mid Coast	Yachats River		X			X	X	X	2X	1,2,3,4
Rogue	Yale Creek	P	P				X			2
Yaquina	Yaquina River		X			X	X	X	2X	1,3
Columbia	Youngs River		X			X	X	X	2X	1,3

X = endangered, threatened, candidate, or species of concern on federal or state list or identified by Nehlsen et al. (1991), or Williams et al. (1989).
P = stock is present in stream.
Spr = spring
Sum = summer
Win = winter

[a]***Other species:*** 1) bull trout, 2) chum salmon, 3) Jenny Creek sucker, 4) Millicoma dace, 5) redband trout, 6) sockeye salmon, 7) Umpqua Oregon chub, 8) Willamette Oregon chub.

[b]***References:*** 1) Frissell (1991), 2) Johnson et al. (1991), 3) Nehlsen et al. (1991), 4) Oregon Chapter of the American Fisheries Society (1991). Draft: Watershed classification/biodiversity list. See Administrative Record.

Table D.13. Washington streams (or stream reaches) identified as containing at least one fish stock that is considered to be at risk.

Basin	Stream	Steelhead Trout Sum	Steelhead Trout Win	Salmon Chinook Spr	Salmon Chinook Sum	Salmon Chinook Fall	Salmon Coho	Sea-run Cutthroat Trout	Other[a]	References[b]
Columbia	Abernathy Creek		X			X			2X	3
Columbia	Alder Creek	X								3
Skagit	Baker River							P	3X,6X,7X	1,3
Quillayute	Bogachiel River							P	3X	1
Columbia	Catherine Creek		X							3
Puget Sound	Chambers Creek						X		2X	3
Grays	Chehalis River							X	3X,4X	1,3
Columbia	Chinook River					X				3
Queets	Clearwater River							P	3X,4X	1
Columbia	Coal Creek		X						2X	3
Columbia	Collins Creek		X							3
Quinault	Cook Creek								4X	2
Mid. Coast	Copalis River							P	3X,4X	1
Coweeman	Coweeman River		X			X		X		3
Cowlitz	Cowlitz River	P	X			X	X	X	2P	1,3
Columbia	Crooked Creek					X			2X	3
Puget Sound	Deschutes River							X	3X,6X	1,3
Hood Canal	Dewatto River		X					P	2P	1,3
Hood Canal	Dosewallips River			X				P	2P	1,3
Hood Canal	Duckabush River		P			X	P	P	2P	1,2,3
Strait JDF	Dungeness River			X		X		P	2P,5X	1,2,3
Puget Sound	Duwamish-Green Rivers			P				P	2X,3X,6X	1
Lewis	East Fork Lewis River	X	X							2,3
Columbia	Elochoman River		X			X	X	X	2X	1,3
Strait JDF	Elwha River			X			X	P	2X,5X,7	1,2,3
Columbia	Entiat River	X		P	P		P		1P	1,2,3
Columbia	Germany Creek		X			X			2X	3
Grays	Grays Harbor							X		3
Columbia	Grays River		X			X	X	X	2X	1,3
Puget Sound	Green River							X		3
Columbia	Hamilton Creek		X					X	2X	3
Columbia	Hardy Creek								2X	3
N. Coast	Hoh River							P	3X	1
Puget Sound	Hood Canal								2X	3
Puget Sound	Hood Canal Tributairies							X		3
Grays	Hoquim River							P	3X,4X	1
Grays	Humptulips River							P	3X,4X	1
Columbia	Jim Crow Creek					X			2X	3
Columbia	Kalama River		X			X	X	X		3
Columbia	Klickitat River	X	X	X				P		1,3
Puget Sound	Lake Washington		X							3
Lewis	Lewis River	P	P	P		X	X	X	1P,2X	1,2,3
Strait JDF	Lyre River						X	P		1,3
Columbia	Major Creek	X	X							3
Hood Canal	Mason Lake							P	3X,6X,7	1
Quinault	McCalla Creek								4X	2
Columbia	Methow River	X			X		P			1,3
Columbia	Mill Creek		X			X			2X	3
Nooksack	North Fork Nooksack River	P	P	X			P		2P	2,3
Puget Sound	Nisqually River			P				P	2X,3X,6X	1
Nooksack	Nooksack River	X	X	P			X	P	3X,6X	1,3
Willapa	North River							P	3X	1
Ozette	Ozette Lake								7X	1,3
Ozette	Ozette River				X	X	X	P	2X	1,3
Snohomish	Pilchuck River							P	3X,6X	1
Puget Sound	Puyallup River			P		X		X	2P,3X,6X	1,3
N. Coast	Queets River							X	3X,4X	1,3
Mid. Coast	Quinalt River							P	3X,4X	1
Columbia	Rock Creek	X	X					X		3
Nooksack	South Fork Nooksack River	P	P	X			P		2P	2,3

continues—

continued—

Basin	Stream	Steelhead Trout Sum	Steelhead Trout Win	Salmon Chinook Spr	Salmon Chinook Sum	Salmon Chinook Fall	Salmon Coho	Sea-run Cutthroat Trout	Other[a]	References[b]
Cowlitz	South Fork Toutle River					X				3
Willapa	Salmon Creek		X					X	2X	3
Puget Sound	Samish River		X					X	3X,6X	1,3
Chehalis	Satsop River	P		P			P	P	3X,4X	1,2
Columbia	Scappoose Creek		X							3
Skagit	Sauk River	P	P	P			P	P	1,2,3X,5,6X	1,2
Puget Sound	Skagit River							X	3X,6X	1,3
Columbia	Skamokawa Creek		X			X	P	P	2P	1,3
Hood Canal	Skokomish River		X	X			P	P	2,3X,5X,6X	1,2,3
Chehalis	Skookumchuck River							P	3X,4X	1
Snohomish	Skykomish River	P	P	P				P	1,3X,5,6X	1,2
Puget Sound	Snohomish River			P				X	3X,6X	1,3
Snohomish	Snoqualmie River	X						P	3X,6X	1,3
Stilla	Stillagumaish River	X		X				X	3X,6X	1,3
Hood Canal	Tahuya River		X					P	2,3X,6X	1,3
Cowlitz	Toutle River		X			X	X	X	2P	1,3
Puget Sound	Tulalip River							X		3
Columbia	Washougal River	X	X			X	X	X	2X	1,3
Columbia	Wenatchee River	X		P			P		1P,7P	1,2,3
Puyallup	White River	P	P	X			P	X	3X,6X	1,2,3
Columbia	White Salmon River	X	X	P		X	P	P	1P	1,2,3
Willapa	Willapa Bay						X		3P	3
Willapa	Willapa River						P	P	3X	1
Columbia	Wind River	X	X					P		1,2,3
Chehalis	Wishkah River							P	3X,4X	1
Columbia	Woodward Creek		X							3
Chehalis	Wynoochee River	P		X				P	3X,4X	1,2,3

X = endangered, threatened, candidate, or species of concern on federal or state list or identified by Nehlsen et al. (1991), or Williams et al. (1989).
P = stock is present in stream.
Spr = spring
Sum = summer
Win = winter

[a]*Other species:* 1) bull trout, 2) chum salmon, 3) Nooky dace, 4) Olympic mudminnow, 5) pink salmon, 6) Salish sucker, 7) sockeye salmon.
[b]*References:* 1) Frissell, (1991), 2) Johnson et al. (1991), 3) Nehlsen et al. (1991).

D.11, D.12, and D.13). These lists include streams with at least one stock identified at risk. These streams could provide habitat connectivity among owl conservation areas. Streams included on these lists may need special consideration when land management activities are planned. If future fisheries inventories reveal additional streams containing these stocks, these streams may need similar considerations. Since data are incomplete on the identification of unique fish stocks across the range of the spotted owl, each stock should be considered individually to reduce the risk of losing a genetically distinct stock.

Ecology of Other Priority Species

Marbled Murrelet *(Brachyramphus marmoratus)*

Distribution.—The marbled murrelet is a seabird that occurs along the Pacific Coast from Alaska to central California throughout the year (Marshall 1988). The species nest in coniferous forests within about 50 miles of the coast in the Northwest and feeds on the ocean immediately offshore, inland marine waters (i.e. Puget Sound), and freshwater lakes (Carter and Sealy 1986, 1987). Known

inland distribution currently decreases north to south, and, to date, the maximum distance the marbled murrelet has been detected inland is 52 miles in the northern Washington Cascades (Eric Cummins, USDI, pers. comm.), 35 miles in Oregon (Nelson 1990), and 24 miles in California (Paton and Ralph 1988). Inland distribution is now discontinuous in all three states due to loss of nesting habitat (Federal Register 56(119);28363).

Status.—In June 1991, the FWS proposed the species for listing as threatened throughout its range in Washington, Oregon, and California, primarily due to the loss of nesting habitat (Federal Register 56(119):28363). At the state and province level, the species currently is listed as endangered in California, sensitive in Oregon and Washington, and threatened in British Columbia. Some legal protection is afforded murrelets in California on state and private lands under the California Forest Practices Act, but not in Oregon or Washington. The California population is considered in danger of extinction because only small isolated poulations and habitat remain, and they may be subject to catastrophic disturbances. As a result of the proposed federal listing of the murrelet, the Forest Service and BLM are consulting informally with the FWS on timber sales within 0.5 mile of occupied habitat (G. Miller, U.S. Fish and Wildlife Service, Portland, Oregon, pers. comm.).

Current population estimates are 1,650 to 2,000 and 2,000 individuals for California and Oregon, respectively (Sowls et al. 1980, Carter and Erickson 1988, Nelson 1990); and 1,900 to 3,500 breeding pairs in Washington (Speich et al. in press). Rodway (1990) estimated the population size as 22,500 in British Columbia. Estimates for Alaska range from 50,000 to 250,000 individuals (Mendenhall 1988). The significance of these figures can be put in context with the historical estimate of 60,000 individuals in the California population prior to logging (Larsen 1991). Ninety-six percent of the historical breeding habitat in California is believed to have been eliminated through logging (Larsen 1991). Similar patterns of habitat loss have occurred throughout forests of the West Coast. Recent estimates suggest a decline of as high as 83 to 88 percent of historical old-growth habitat (Spies and Franklin 1988, Morrison 1988, Norse 1990).

Natural history and habitat associations.—Throughout the species' range, murrelets show a strong dependence on old-growth or mature forests with an old-growth component for nesting (Nelson 1990, Carter and Erickson 1988, Ralph et al. 1990, Paton and Ralph 1988, Hamer 1991). Plant community associations include redwood and Douglas-fir in California, and Douglas-fir, western hemlock, western red cedar, and Sitka spruce in Oregon and Washington. Of 23 nests located to date from Alaska to California, all were in old-growth or mature trees. Nest trees (n=16) averaged 73-inch dbh (range 35 to 106 inches) (S.K. Nelson, Oregon State University, Corvallis, pers. comm.). Nests were primarily on large or deformed limbs with a moss substrate used for nesting. Seventy percent of the inland records of downy young and fledglings compiled by Carter and Sealy (1987) were from old-growth forests and the remainder were located near old-growth. Many additional young and egg remnants have since been located in Washington, all in older forests (Cummins 1991).

In Oregon, Nelson (1990) found that murrelets were most abundant within 12 miles of the coast and decreased significantly from there inland. From stratified random surveys in Oregon, forest stands occupied by murrelets were larger than random sites (Nelson 1990). Larger stands of old-growth in California also had significantly higher numbers of detections of murrelets than smaller stands. The average number of detections also increased as the number of large trees in the stands increased (Paton and Ralph 1988).

In Oregon, stands occupied by murrelets ranged from 25 acres to more than 2,000 acres with a mean of 480 acres. In California the range was 40 to 28,000 acres (S.K. Nelson, Oregon State University, Corvallis, pers. comm.). The relationship between stand size and murrelet productivity is unknown, but smaller stand sizes and greater landscape fragmentation may expose nesting birds to increased predation. Of 21 nests located, in which the nesting outcome was known, 48 percent were lost to predation (S.K. Nelson, Oregon State University, Corvallis, pers. comm.).

In all three states, the remaining habitat is primarily on public lands. In Washington, significant population numbers are located only in the North Cascades and Olympic Peninsula, with remnant pockets of suitable habitat located within the southwest corner of the state just north of the Columbia River. In Oregon, two-thirds of the remaining population occurs in the central Coast Range in the Siuslaw National Forest and scattered BLM lands. The remainder is found along the southwest coast in the Siskiyou National Forest. In California, the current population exists primarily in state or federal parks and private lands along the north coast and near Santa Cruz in state parks. In California, an estimated 60,000 acres of old-growth remain in these areas and another 10,000 acres still exist on private commercial forest lands (Larsen 1991).

Bald Eagle (Haliaeetus leucocephalus)

Distribution.—Bald eagles occur throughout the North American continent from northern Alaska and Canada to southern United States and Baja California. Their breeding range includes most of Alaska (except the north slope), southern Canada, the northern United States, and parts of the east and west coasts (Stalmaster 1987). Because they migrate south in the winter to avoid severe winters and shortage of food, their winter distribution is substantially south of their breeding range. Their winter range includes northwestern and central states and the Alaskan and Canadian seacoasts, where large concentrations occur. Breeding and wintering populations occur along the east coast. The largest breeding populations in the contiguous United States occur in Florida, the Great Lakes states, Chesapeake Bay, and the Pacific Northwest. Wintering populations are much more abundant because of the large number of migrants from Alaska and Canada that come to the lower 48 states. Alaska has a wintering population of 35,000 to 45,000, and Washington has the largest winter population in the contiguous states (Stalmaster 1987).

In the Pacific Northwest, the largest populations of breeding eagles occur in the San Juan Islands, Puget Trough, and Olympic Peninsula of Washington; the Klamath Basin and Cascade lakes of Oregon; and Shasta Lake of California. The largest wintering concentration occurs in the Klamath Basin of southern Oregon and northern California where more than 1,000 eagles have been counted in one day (R. Opp, Oregon Department Fish and Wildlife Research Unit, Corvallis, Oregon, pers. comm.). Another large population occurs along the Skagit and Nooksack Rivers in northwest Washington.

Status—The bald eagle is listed as federally threatened in Washington and Oregon and endangered in California. Breeding populations have been increasing in the Pacific Northwest during the last 15 years as a result of the banning of the pesticide DDT (Henny and Anthony 1989), and winter populations have remained stable or have increased during this time. As of 1990, there were approximately 530, 210, and 108 nesting territories in the states of Washington, Oregon, and California, respectively. Of those, approximately 70 percent are on federal lands, and the remainder are on state and private lands in Oregon and California. Conversely, about 60 percent of the nesting territories are on state and private lands in Washington. More than 95 percent of the

nesting territories in the three states are within the range of the northern spotted owl. There are 130, 76, and six known communal roosts in Washington, Oregon, and California, respectively. More than 95 percent of the communal roosts also are within the range of the owl in Washington and California, whereas less than 10 percent of the roosts in Oregon are within the range of the owl.

Natural history and habitat associations.—The bald eagle is the only member of the fish-eating eagle group in North America. It is free ranging for much of its life except in southern or coastal areas where eagles form resident breeding populations throughout the year. The bald eagle forages over water throughout most of its range and for most parts of the year, so its prey is derived from nonforested habitats. Prey consists primarily of fish during the breeding season and waterfowl or carrion during the winter (Stalmaster 1987). However, eagles nest and roost communally in forested habitats throughout their geographic range. Selection of areas for nesting and communal roosting is predominantly in coniferous forests that contain some component of older forests, and these areas are considered essential habitat features for the species (Keister and Anthony 1983, Anthony and Isaacs 1989). The Pacific States Bald Eagle Recovery Plan (USDI 1986) recognizes the importance of nesting and roosting areas, and it is important to manage these two habitats properly, because timber harvest can have an adverse impact on them.

Present threats to bald eagle populations include illegal shooting, pesticides, human disturbance of foraging and nesting areas, and habitat destruction. The effects of pesticides have decreased since the banning of DDT, but there is still low reproductive success of breeding pairs on the lower Columbia River, which is associated with high levels of DDE and PCBs (Garrett et al. 1987). The increase in human populations and amount of leisure time for recreation has resulted in an increase in human-eagle interactions, and human disturbance has been reported to have effects on nesting (Anthony and Isaacs 1989) and foraging populations (McGarigal et al. 1991, Stalmaster 1987:161). This threat may become more important over time. Habitat destruction is a problem primarily on nonfederal lands where only nest trees and small, surrounding stands of trees are reserved from logging. These nest trees and stands are highly vulnerable to windthrow and other natural mortality.

Northern Goshawk (*Accipiter gentilis*)

Distribution.—The northern goshawk inhabits coniferous and deciduous forests in temperate and subarctic regions of the northern hemisphere. In North America, goshawks are known to breed as far south as the Appalachian Mountains in the Southeast and throughout the Rocky Mountains into Mexico. In the western United States, the species nests as far south as the Sierra Nevada Mountains of California and the Kaibab Plateau of northern Arizona (Reynolds 1989). The goshawk is an uncommon resident in California. Nesting goshawks have been recorded as far south as Tulare County in the Sierra Nevada, and in the Coast Range to Mendocino County (Grinnell and Miller 1944). Summer sightings of goshawks near Mt. Pinos and in the San Jacinto Mountains suggest that isolated breeding populations may have persisted up to the 1970s.

In Oregon, nesting goshawks have been located in the Cascade, Klamath, Ochoco, and Blue Mountains, and smaller ranges in eastern Oregon. Although goshawks are not known to nest in the central or northern portions of the Oregon Coast Range, nests have been located in the Siskiyou Mountains in southwestern Oregon (Marshall 1991). Goshawks breed in all of Washington's forested montane areas, including the Olympic Peninsula, the entire Cascade

Range, the Blue and Okanogan Mountains, and the Selkirk Mountains (Fleming 1987).

Status.—Goshawks historically nested throughout the forested regions of temperate North America. By the 1930s however, breeding populations in the eastern United States were much reduced (Bent 1937). The status of the goshawk is not well known for much of the western United States. Most authors believe that the species has declined substantially since the turn of the century, primarily as a result of habitat loss attributed to intensive timber harvest. Bloom et al. (1985) estimated that goshawk populations in California had decreased by 30 percent from historic levels by 1985, with continuing declines of approximately 1 percent per year. Mannan and Meslow (1984) speculated that goshawks could be extirpated from northeastern Oregon forests under timber management regimes that resulted in the liquidation of most of the old-growth forest in the area. Patla (1991) documented an 80 percent decrease in occupancy rates for goshawks in habitat adjacent to timber sales, despite the establishment of buffers around the immediate nest sites. Buffers apparently were unsuccessful in Arizona as well, as Crocker-Bedford (1990) suggested declines of as much as 90 percent in nest occupancy and productivity for an isolated population in northern Arizona.

The goshawk is classified as "critical" on the Oregon sensitive species list. "Critical" indicates a species for which listing is pending or for which listing may be appropriate if immediate conservation actions are not taken (Oregon Department Fish and Wildlife 1991b). The states of Washington and California also list the northern goshawk as a candidate for state listing and a sensitive species, respectively (Washington Department Wildlife 1991b, California Fish and Game 1990). In July 1991, a petition was filed with the FWS for emergency listing of an isolated population of goshawks in the southwestern United States. More recently, the species has been petitioned for listing throughout the western United States. The goshawk is a management indicator species for old-growth dependent species on the Deschutes, Fremont, Wallowa-Whitman, and Winema National Forests in Oregon, and the Inyo, Klamath, Six Rivers, and Shasta-Trinity National Forests in California.

Natural history and habitat associations.—Goshawks may be found in deciduous and coniferous forest types, where they typically select nest sites in dense, single-storied mature to old-growth forests with high canopy closure and poorly developed understories. Nest trees tend to be significantly larger in diameter than those of the surrounding stand; nest stands, in turn, often are more dense and include larger diameter stems than adjacent forest stands (Buchanan 1991, Fleming 1987). Snags, stumps, and down logs are important as plucking perches, which are generally located within 55 yards of the nest. This general characterization holds for goshawk nests from the Olympic Peninsula (Fleming 1987), south to California and northern Arizona (Austin 1989, Reynolds 1989, Hall 1984), and east into the northern Rockies (Hayward et al. 1990).

Ongoing research and decades of nest records and incidental sightings indicate that goshawks in western North America find optimal habitat in mature and old-growth coniferous forests. The vertical and horizontal structure of older forests contributes to accessible prey and nest sites (trees) substantial enough to support the bulky stick nest. The strength of the association may vary. In Oregon, all but one of 74 nests located by Reynolds were situated in dense mature or old-growth stands (Reynolds and Wight 1978). Loss of breeding and wintering habitat resulting from harvest of old-growth, reproductive failure, and human disturbance were the primary limiting factors for goshawks (Reynolds 1989). The liquidation of older forests and increasing fragmentation of suitable habitat are probably the most significant threats to goshawks.

However, little is known about the ecology of the species in western Oregon and Washington.

Gray Wolf (Canis lupus)

Distribution.—Wolves formerly occurred throughout the Northern Hemisphere above 20 degrees north latitude in all habitats except deserts. Now they are restricted to the northern portions of North America (primarily Alaska, Canada, and states bordering Canada), eastern Europe, the Soviet Union, China, and northern India. Remnant populations occur in western Europe and Scandinavia and some may remain in Mexico (Mech 1974). Historically, wolves ranged over all of Washington, Oregon, and California. The wolf was extirpated from Washington by the early 1900s and current sightings suggest it has reestablished itself in the mountainous areas of northern Washington (Hansen 1986).

Status.—The gray wolf is listed as endangered under federal and Washington State Law. It is extirpated in Oregon and California. Three breeding occurrences (dens) of gray wolves were documented in the North Cascades of Washington during the spring and summer of 1990. Wolf pups and adults were seen or heard in the North Cascades National Park Service Complex, in the Okanogan National Forest, and in the Wenatchee National Forest. Two of the breeding observations of wolves are near spotted owl habitat conservation areas as proposed by Thomas et al. (1990). These breeding occurrences and reports of individual wolves in the Cascades, Okanogan Highlands, and Selkirk Mountains likely indicate a southern range extension of gray wolf populations from British Columbia.

Natural history and habitat associations.—Forested and open habitats supporting ungulate populations are the primary requirements of the gray wolf. Areas that support small mammal populations may be seasonally important for wolves. Gray wolf populations are typically organized into social packs of two to 20 individuals. Each pack usually comprises a mated pair and their offspring from several generations. Since each pack consists of several animals, habitat management must consider the food requirements of a large number of wolves, rather than isolated individuals. Wolf pack territories may range in size from 40 to 1,000 square miles. These territories must provide adequate year-round prey (ungulates and small mammals) and secure den sites for birth and rearing pups. Dens usually are located in a slightly elevated area of soft soil that provides a dry, easily-excavated site. Denning sites often receive traditional use and usually are secluded, but occasionally are located near human activity. Rendezvous sites are used for raising pups and are located within 1 to 5 miles of the den in an open area near water. Wolves are particularly sensitive to human activity near den and rendezvous sites (USDI 1987).

Human-induced mortality is the major limiting factor affecting the survival of the gray wolf over most of its range. Wolf predation on livestock can cause conflicts with humans, and misconceptions about wolves often lead to indiscriminate shooting. In the absence of human-induced mortality, year-round prey availability is the most significant limiting factor affecting the survival of individual wolves, packs, and local wolf populations (USDI 1987). Although wolves are not particularly associated with older forests, they may benefit from DCAs if they remain roadless and free from human disturbance.

Grizzly Bear (Ursus arctos)

Distribution.—The historic range of the grizzly bear included western North America, roughly from the Mississippi River and Canadian Great Plains west to the Pacific Ocean and from Alaska and the Northwest Territories south to central Mexico. The current range is from the Rocky Mountain east front in Canada, Montana, and Wyoming to the Pacific Ocean and from Alaska and the Northwest Territories south to portions of Washington, Idaho, Montana, Wyoming, and perhaps Colorado. Current grizzly bear range is less than 2 percent of the historic range in the lower 48 States, and populations number less than 1,000 (USDI 1990). Although the north Cascades and Selkirk Mountains are recognized as grizzly bear ecosystems in the Grizzly Bear Recovery Plan, bears may occur in the Okanogan Highlands and Kettle Range as well (J.A. Almack, Washington Department Wildlife, Olympia, pers. comm.). The remote areas occupied by grizzly bears are primarily on federal lands. The Selkirk ecosystem is designated as a recovery area and the north Cascades is being evaluated to determine if it is capable of supporting a viable population of grizzly bears. In one 5-year study, four sets of confirmed grizzly bear tracks were found in the north Cascades of Washington. One grizzly bear skull and a food cache also were found. Washington Department of Wildlife biologists evaluated a total of 128 reports of grizzly bear observations in the north Cascades. These observations, combined with other incidental sightings, indicate that there is a small, resident population of grizzly bears in the north Cascades. A technical review team will determine the capability of the north Cascades to support a viable population of grizzly bears and the FWS will decide whether to designate this area as a recovery zone (Washington Department of Wildlife 1990).

Status.—The grizzly bear is federally listed as threatened and state listed as endangered in Washington. It is extirpated in Oregon and California. A petition was submitted to the FWS in 1990 to have the grizzly bear in the north Cascades listed as an endangered, rather than a threatened species. The FWS found the petition was substantive and undertook a review of the bear's status; a final finding on the petition has not been made.

Natural History and Habitat Associations.—Grizzly bears remain only in vast, diverse, and remote mountainous habitat. They require a variety of vegetation types for food and for breeding, bedding, and denning activities. These habitats include open areas such as lowland wet meadows and marshes, shrub fields located in avalanche chutes, high elevation sedge or heath meadows, and stream floodplains. Forest cover is used for resting and hiding cover. The importance of these habitats to bears varies during the year, and often is determined by the availability of seasonally important foods. Plant materials, including succulent grasses, sedges, forbs, and fruits; fish; and large mammals are major components of the diet. Carrion, insects, and small mammals such as ground squirrels also are consumed. Grizzly bears usually prepare winter dens in excavated chambers or natural caves located above 5,000 feet on slopes with deep snow. Den sites must have well-drained, soil, and must be isolated from humans and other animals (Almack 1985).

Human-induced mortality is the major limiting factor restricting grizzly bear populations south of Canada. Availability of seasonally important habitats may be critical to the survival of specific grizzly bear populations. Grizzly bears require large tracts of suitable habitat that are managed to minimize conflicts with humans (USDI 1990). Grizzly bears, like wolves, are not dependent on old-growth forests, but they may benefit from DCAs that remain roadless and free from human disturbance.

Fisher *(Martes pennanti)*

Distribution.—The range of the fisher (a small mammalian carnivore) extends south from the forests of central and southeastern Canada to New England and the Great Lakes states in the east and from British Columbia to western Montana and the Sierra Nevada mountains of California in the west (Arthur et al. 1989, Strickland et al. 1982). Prior to European settlement, the fisher occupied all densely forested areas of Washington, with the most dense populations located on the Olympic Peninsula (K. Aubry, U.S. Forest Service, Olympia, Washington, pers. comm. 1991). Although rare, the fisher still occurs in the Cascades, Okanogan Highlands, and the Olympic Peninsula (K. Aubry, U.S. Forest Service, Olympia, Washington, pers. comm. 1991). At one time, the fisher probably was present in all Oregon counties where coniferous forests occurred. Today, the species is known to inhabit forested portions of the Cascade, Klamath, Siskiyou, and Blue Mountains (Marshall 1991). There are few recent reports from the Coast Range, although a fisher sighting was reported from the Hebo Ranger District, Lincoln County in 1991. The range of the fisher in California extends from the Oregon border in the northwest south to Lake and Sonoma Counties. To the east, the species has been found near Clear Lake in Lassen County, and as far south as Greenhorn Mountain, Kern County. Fishers range from near sea level in the low coastal areas to above 11,000 feet in the Sierra Nevada (California Department Fish and Game 1986).

Status.— A petition was filed with the U.S. Fish and Wildlife Service in 1990 to list the fisher as a threatened species in California, Oregon, and Washington. The petition was denied, based on the inconclusive nature of the information it provided. An interagency working group subsequently was formed to facilitate sharing on new information of fishers and the FWS included the fisher among its candidate species in 1991. During the last decade, sightings of fishers have been recorded in Mt. Rainier, Olympic, and North Cascades National Parks in Washington, but no formal surveys were conducted. Ongoing investigations in Olympic National Park indicate that the fisher may have been extirpated from the Olympic Peninsula as a result of extensive habitat alteration (K. Aubry, U.S. Forest Service, Olympia, Washington, pers. comm. 1991). The fisher is a "candidate" species for listing as threatened or endangered in Washington.

Trapping and incidental loss caused by nontarget strychnine poisoning (from wolf and coyote baits) resulted in declines in Oregon fisher populations by the 1930s (Irwin 1987). Trapping for fishers has been prohibited in Oregon since 1937, but after more than 50 years, populations do not seem to have recovered (Marshall 1991). In 1961, 24 fishers were transplanted from British Columbia to Klamath and Union Counties. No post-release monitoring was conducted, and the status of any resulting fisher population is unknown (Marshall 1991). Incidental sightings in the Cascade, Siskiyou, and Coast Range Mountains continue to be reported, but no standardized surveys have been undertaken to assess population status at the state level (Marshall 1991). The fisher is listed as a sensitive species in Oregon and California. Schempf and White (1977) suggested that fishers were relatively common in the northern coastal mountains of California, but were uncommon or rare in the Sierra Nevada.

Natural history and habitat associations.—Fishers inhabit coniferous and mixed coniferous/deciduous forests. Dense, mature to old-growth forests are preferred during summer for cover and den sites (Jones 1991, Marshall 1991, Washington Department Wildlife 1991b). In Idaho, stands used by fishers during the breeding season had more snags, logs, and large-diameter trees relative to all available habitat. Stands of pole-sized or smaller trees were avoided, as were open, drier habitats. Jones (1991) reported a preference for

forested riparian habitats. Fishers in California selected coniferous forests with a hardwood component for summer habitat (Marshall 1991).

Several authors suggest that fishers select habitats with a high degree of overhead cover and avoid large openings (Strickland et al. 1982, Marshall 1991). In Maine, where population densities are quite high in comparison to populations in the western states, fishers are tolerant of low-density rural development and will cross roads and farm fields to travel among forested stands. Summer resting sites may be situated in hollow snags, under logs, brush piles, or root wads. Maternal dens usually are situated high in a hollow snag.

Fishers may use a wider variety of habitats during winter than in summer. Forest structure and prey availability are probably the critical factors in the selection of winter habitat. Jones (1991) found that old-growth stands were important winter habitats for fishers in Idaho, but second-growth stands also were used. Fishers select stands with large remnant trees and/or logs that have survived earlier fires in second-growth. Fishers appeared to select forested riparian areas in winter as well as in summer. Allen (1983) concluded that stands having a high degree of coniferous tree canopy closure provided optimal winter habitat. Jones (1991) found no indication that snow conditions influenced winter habitat use by fishers; other authors suggest that fishers may move to lower elevations to avoid deep snow or to find prey (Marshall 1991).

Small to medium-sized mammals, birds, and carrion dominate the diet of the fisher; however vegetation, molluscs, and other invertebrates also have been identified from digestive tracts (Jones 1991, Arthur et al. 1989). Porcupines are a major prey species wherever they occur within the range of the fisher (Strickland et al. 1982). Red-backed voles and flying squirrels are important prey for the fisher in Idaho and Oregon (Ingram 1973). Grenfell and Fasenfest (1979) found false truffles (*Rhizopogon*) to be an important food of fishers in northern California. Fishers may be common locally in parts of northern California and Maine (California Fish and Game 1986, Arthur 1987); otherwise the species occurs at low densities.

Most authors concur that mature and old-growth forests are important habitats for fishers. While some believe fishers require large contiguous stands of old-growth (Marshall 1991, Washington Department Wildlife 1991b), others emphasize an apparent selection for habitat diversity within the home range (Strickland et al. 1982). Given the large home ranges of fishers, these two views may not be contradictory.

Marten (*Martes americana*)

Distribution.—The marten (a small mammalian carnivore) inhabits the boreal forests of North America from Canada and Alaska south to California, Idaho, western Montana, Colorado, Utah, and New Mexico in the west, and the Great Lakes states and northern New England in the east. Historically, the species was common throughout the northeastern United States and most of Canada. Loss of habitat compounded by commercial trapping resulted in the extirpation of martens from most of New England and portions of southeastern Canada by the 1930s (Clark et al. 1987, deVos 1964).

Martens have been recorded from most of the mountainous areas of Washington including the Blue, Cascade, Olympic and Selkirk Mountains, the Okanogan Highlands, the coastal ranges and Vancouver Island. Populations are most dense in the Cascades, Selkirks, and Okanogan Highlands (Washington Department Wildlife 1991b). All of the major mountain ranges in Oregon

at one time supported marten populations. The species now occurs primarily in the Cascade, Siskiyou, Wallowa, and Blue Mountains; a few recent records also exist for the Coast Range and the Fremont National Forest in southeastern Oregon (Marshall 1991). *Martes americana humboldtensis* occurs in the coastal coniferous forests of California from Sonoma County north into southwestern Oregon, where it inhabits areas from sea level to more than 4,000 feet in elevation (Grinnell et al. 1937).

Status.—In Washington and Oregon, martens are trapped commercially despite their status as sensitive species. Designation as a "priority species" in Washington is aimed at providing guidance for habitat retention and enhancement (Washington Department of Wildlife 1991b). Marshall (1991) speculated that the marten in Oregon has declined in numbers in the Coast Range, and viable populations no longer may exist there. Martens probably are most abundant in Oregon in the central and southern Cascades and in the Blue Mountains. The *M.a. humboldtensis* subspecies is listed as sensitive in California. Here, as in other parts of its range, the marten may be vulnerable to overtrapping (Clark et al. 1987).

Natural history and habitat associations.—The marten is a management indicator species for old-growth habitats in several national forests in California and most national forests in Oregon and Washington. Martens are known to use a variety of coniferous forest types, and optimal habitat appears to be moist subalpine fir communities more than 100 years old (Koehler et al. 1975). In the Pacific Northwest, martens select dense, mature or old-growth coniferous forests having abundant standing snags and down woody debris (Buskirk 1984, Irwin 1987, Hargis and McCullough 1984, Spencer 1981). Martens apparently avoid large open areas within their territories. Hargis (1981) noted that martens would cross but not hunt in small openings during winter, while in northern California, martens avoided open areas during all seasons, rarely venturing more than 10 yards into open meadows (Spencer 1981, Spencer et al. 1983). Martens may avoid openings during winter if a combination of deep snow and lack of exposed logs and stumps deny access to prey beneath the snow (Hargis and McCullough 1984, Koehler et al. 1975). Avoidance of openings also may be a defense against aerial predators such as golden eagles and great horned owls (Raine 1982, Hargis and McCullough 1984).

Hargis (1981), Spencer (1981), and Jones and Raphael (1991) have documented the marten's affinity for riparian habitats, which are important for their abundant food and dense cover. In California, Spencer (1981) found riparian areas were used heavily for foraging, while Jones and Raphael (1991) reported more resting sites in streamside than in upland plant communities in Washington. Summer resting sites have been located in live trees, standing snags, slash piles, and hollow logs. Where these components are limited, rock slides or the tree canopy may suffice (Irwin 1987, Jones and Raphael 1991). Large old trees, snags, and large hollow logs are also important as denning sites. Down woody material, an important component of marten habitat, is especially critical in winter for energy conservation and access to prey. In the central Rocky Mountains, Buskirk et al. (1989) found that martens selected partially decayed stumps and logs as resting sites. They suggested that decomposing wood provided much more effective insulation than snow, allowing martens to conserve energy. Because martens do not hibernate or store large amounts of fat before the onset of winter (Washington Department of Wildlife 1991b), maintenance of a positive energy balance is critical to overwinter survival. Stumps, logs, tree wells, and slash piles also provide access to prey under snow cover. Although martens are capable of digging through snow to capture prey, use of woody debris to reach prey is probably energetically less costly (Hargis and McCullough 1984).

Home range size of martens varies with population density, food abundance and sex (Buskirk et al. 1989, Clark et al. 1987). Martens are opportunistic foragers that will feed on a wide variety of small mammals, birds, reptiles, invertebrates, and plants depending on availability. In Oregon, red-backed voles, flying squirrels, and Douglas' squirrels are important winter prey (Irwin 1987, Marshall 1991). Fruits, insects, and birds, mostly absent from the winter diet, may comprise a significant proportion of the summer diet (Irwin 1987). The close association of martens with mature and old-growth coniferous forests has been confirmed in numerous investigations (Irwin 1987, Jones and Raphael 1991, Hargis 1981, Koehler et al. 1975). High canopy closure and abundant coarse woody debris are the two most important components of marten habitat provided by old-growth forests. Forest cover and large woody debris are critical in winter, when they provide cover from predators and insulation from harsh winter conditions. Loss of habitat and timber harvest are the primary limiting factors for marten populations in the Pacific Northwest (Irwin 1987, Marshall 1991, Washington Department of Wildlife 1991b). Clear-cutting and stand-replacing fires significantly have reduced the amount of mature and old-growth habitat available. Over-harvesting by commercial trapping is a major concern for martens in California (Grinnell et al. 1937, G. Gould, Klamath National Forest, California, pers. comm.) and also may be a problem in Washington, where martens are concurrently listed as "game" and as "sensitive." Marten trapping continues in Oregon, but to a limited degree (Irwin 1987).

Amphibians

The committee solicited an account of the ecology of amphibians and reptiles (Beatty et al. 1991) in the course of its examination of other species. The following treatment is extracted from that report.

Twenty-three species or species groups of amphibians and reptiles were identified whose ranges overlap with the distribution of the northern spotted owl and whose ecological requirements appear to be linked with the remaining distribution of older forest ecosystems in the Pacific Northwest. These species represent approximately 40 percent of the extant amphibians and reptiles in the region (Nussbaum et al. 1983, Stebbins 1985). Within this group of animals, eight were designated as priority species by the committee. They are the Olympic salamander (four species), the Oregon slender salamander, Pacific giant salamander, Cope's giant salamander, Del Norte salamander, the Larch Mountain salamander, the Siskiyou Mountain salamander, and the tailed frog.

The reasons for selecting these animals as a subset of the 23 species or species groups center on at least two characteristics they share. One is their relatively limited distribution. (Figures D.2 - D.4) The other is with their apparently narrow ecological requirements in comparison with close relatives. Distributions are fairly well worked out for most of these animals, but more field work may reveal new populations in what most herpetologists would consider novel habitats. Examples of this finding include the discovery of Larch Mountain salamanders in the central Cascades of Washington (Aubry et al. 1987) and the Oregon slender salamander east of the Cascade crest (Kirk and Forbes 1991). A related point is that not much is known about the precise ecological requirements of many of these species. Research indicates that amphibian populations may be a significant component, and may play an important functional role in ecosystems, especially with respect to energy flow through the systems.

One of the important characteristics of these animals' biology is the genetic structure of their populations. Evidence indicates that, at least for salamanders, there is considerable genetic differentiation among populations (Wake and Yanev 1986; Good 1989). The results of these studies indicate that

each population of these animals is genetically unique and that when one population is extirpated, a portion of the genetic diversity within the species in question is lost and probably is not recoverable. This information, coupled with the concerns raised by Blaustein and Wake (1990) with respect to recent global declines in many amphibian populations, calls for careful consideration of the impacts of management practices on populations of these animals.

Del Norte Salamander (*Plethodon elongatus*)

Distribution and habitat.—The Del Norte salamander occurs in humid coastal forests from near Port Orford, Curry County and Powers, Coos County, Oregon; to near Orick, Humboldt County, California, and inland to near Salyer, Trinity County, and Seiad Valley, Siskiyou County, California, from sea level to around 3,900 feet (1,200 meters) (Stebbins 1985). It is often found in rock rubble of old riverbeds, road fills, outcrops, and moss-covered talus. It generally occurs in drier situations than the Dunn's salamander. Stebbins (1985) and Herrington (1988) found that the Del Norte salamander occurred almost entirely in forested talus areas. Using time-constrained search methods, Raphael (1988) found the species present in all six of his forest seral stages but most abundant in mature and old-growth timber. Abundance seemed correlated with a hardwood understory. Welsh and Lind (1988) found this species to have a higher abundance in older forest stands and a lower relative abundance on drier stands. Welsh (1990) considered the Del Norte salamander (along with the Olympic salamander and the tailed frog) to be a species long associated with elements of the arcto-tertiary forest.

Ecology and management.—Welsh (1990) stated that the close association of the Del Norte salamander with old-growth forests probably is due to the presence of microhabitat and microclimate factors that occur there, and that the species has evolved with habitats existing only in these forests. The species retreats to deeper crevices in talus during hot, dry, or cold periods, but may occur under surface objects during warm, wet weather (J. Beatty, Oregon State University, Corvallis, pers. obser). The Del Norte salamander has a fairly limited distribution in southwestern Oregon and northwestern California. Within its range, it most often occurs in moist (not wet) situations, usually associated with talus or outcrops in older forests. Raphael (1988) has estimated that removal of old-growth fir forest within its range would result in a 75 percent population reduction. Because of its restricted range and association with older forests, no timber harvest should be considered in conservation areas where this species occurs.

Siskiyou Mountain Salamander (*Plethodon stormi*)

Distribution and habitat.—The Siskiyou Mountain salamander occurs in Jackson County, Oregon, and northern Siskiyou County, California. It is not sympatric with any other *Plethodon*, but occurs within 9 miles of *P. elongatus* (Brodie 1971). Populations of *P. stormi* are associated closely with talus deposits and fissured rock outcrops. Individuals occasionally may be found under coarse woody debris, but only during the wettest weather and always near talus. Populations are densest on heavily wooded, north-facing slopes with talus (Nussbaum et al. 1983).

Ecology and management.—Soil temperatures where *P. stormi* have been collected during daytime were 3.5° to 11.3°C. Individuals are closest to the surface during spring (March to April) and fall (September to early November). However, even in dry summer weather, some may come to the surface to feed at night. They usually lie with their heads near the opening of their shelter

and dart forward to snap up small invertebrates. During wet weather, they may crawl over the surface of a talus slope (Nussbaum et al. 1983).

Larch Mountain Salamander *(Plethodon larselli)*

Distribution and habitat.—The Larch Mountain salamander has a very restricted range (Herrington and Larsen 1985). It is found only along a 35-mile stretch of the Columbia River Gorge in Washington and Oregon and in other locations in southern Washington (Aubrey et al. 1987). It appears to have narrow habitat requirements in stabilized talus ranging in size from one-third to 2 inches with soil deposits in the spaces. No data exist regarding population dynamics of this species. The animals behave as most plethodontid salamanders do; they are active at or near the surface whenever temperature and moisture regimes permit, which could be any day of the year in the Columbia River Gorge (Herrington and Larson 1985, 1987).

Herrington and Larsen (1985) make a case for a dependent relationship between this salamander and old-growth forests based on one case. One of their sites (Mabee Mines Road in Skamania County, Washington) was comprised of two talus slopes separated by a creek. One talus slope had been clear-cut 10 years before their study and no *P. larselli* were found in the clearing. The talus slope directly across the creek from the cut slope contained a population of Larch Mountain salamanders.

Ecology and management.—Herrington and Larson (1985) go on to state that the Columbia River Gorge is a geographic area with many potential uses, many of which could affect populations of these salamanders. Any land use practice that alters moisture regimes in suitable stabilized talus slopes may cause extirpation of populations of *P. larselli*. Logging, harvesting talus for road building, and housing developments may affect this species adversely, but it is not well documented.

The Larch Mountain salamander has an extremely limited range and narrow habitat requirements. The species appears to be an old-growth obligate within most areas of its range (Beatty et al. 1991). Based upon the two points above and other factors, Herrington and Larson (1985) recommend that this species be listed as threatened, despite their having discovered new populations in Washington. Clearly, this is an animal of special concern. Based on personal observations by J. Beatty (Oregon State University, pers. comm.), it appears that this species must have protection of some kind (in terms of habitat preservation) if viable populations are to be retained. Every effort should be made to provide stabilized talus areas in older forests within its range.

Oregon Slender Salamander *(Batrachoseps wrighti)*

Distribution and habitat.—The Oregon slender salamander occurs only in Oregon along the forested west slopes of the Cascades from the Columbia River south to southern Lane County and ranges in elevation from about 50 feet in the Columbia Gorge to near 4,300 feet in the Cascade Mountains. The species recently has been collected in Wasco County, Oregon, extending its distribution east of the Cascades crest (Nussbaum et al. 1983, Stebbins 1985, Kirk 1991).

The Oregon slender salamander appears to be most common in mature Douglas-fir forests on west slopes of the Cascades, but it also occurs in second-growth forest, and in fairly recent lava flows a few miles west of Santiam Pass, Linn County. It is seldom found in clear-cuts, but has been collected under surface debris in open, second-growth forests during a damp spring. The

species also is found under the bark of decaying Douglas-fir logs or deep within such logs (Nussbaum et al. 1983, R. Storm, pers. obser.). It also frequents moist woods of Douglas-fir, maple, hemlock, and red cedar (Stebbins 1985). In late spring and summer, it retreats to underground refugia (Nussbaum et al. 1983).

Bury and Corn (1988) found *B. wrighti* in damp to wet old-growth, in mature forest, and in clear-cuts. Within these areas, they found 62.3 percent inside logs and 87 percent in or near logs. They state, "The Oregon slender salamander seems to be associated with coarse woody debris in older decay classes, which is a characteristic feature of old-growth forests." Herrington (1988) observed *B. wrighti* in talus habitats more often than in other areas. This species was included in a list of species that he believed were capable of carrying out their entire life cycle within talus habitats.

Ecology and Management.—Substrate temperatures where salamanders were found in May varied from 10.8° to 13.8° C (Nussbaum et al. 1983). Stebbins (1951) gives good details of his collection sites, indicating microhabitat preferences. Individuals of this species often are found clumped, with two or more being together under the same object. When disturbed, they usually coil their bodies like a watchspring and if further disturbed, flip about violently by coiling and uncoiling their bodies. If seized by the tail, *B. wrighti* can shed it at any segment. Near Hidden Lake, Lane County, Oregon, 13 percent of the adults lacked tails or were regenerating them (Nussbaum et al. 1983, Stebbins 1951).

The Oregon slender salamander is endemic to the forested west slopes of the Oregon Cascades north of southern Lane County, Oregon. Studies have shown it to prefer older forests and to use, with frequency, large decaying logs typical of such forests. Further studies of precise ecological requirements are needed, but it seems obvious that harvesting of older forests has a high likelihood of affecting populations of this species (Beatty et al. 1991). Therefore, older forest preserves would benefit this species.

Giant Salamanders (Dicamptodon spp.)

Since all Dicamptodon share similar habitat requirements and reproductive biology, they will be discussed as a single entity, except where appropriate. These animals are probably the largest terrestrial caudate amphibians.

Detailed historical descriptions of the genus and *D. ensatus* are provided by Anderson (1969) and Nussbaum (1976). Nussbaum (1970) described the first cryptic species (*D. copei*) within the genus, and Good (1989) detailed the biochemical evidence he used to describe additional enigmatic taxa within *D. ensatus*. Electrophoretic studies (Daugherty et al. 1983, Good 1989) indicate that there may be biologically significant levels of genetic discontinuity between groups of populations throughout the range. Moreover, the observed heterogeneity among the groups is consistent with that which is used to differentiate species. Thus, these scientists have elected to split D. ensatus into a group of three cryptic species, two of which are within the range of the northern spotted owl (*D. copei* and *D. tenebrosus*). This adds new responsibilities to the construction of any management plan for this array of salamanders.

Distribution and habitat.—Disjunct populations inhabiting the Rocky Mountains of Idaho and Montana (see range map) have been designated *D. aterrimus* by Good (1989) and Daugherty et al. (1983). Populations of concern to this report are found in northwestern California, Oregon, Washington, and extreme

southwestern British Columbia. Good's (1989) *D. ensatus* is found in the San Francisco Bay area, his *D. tenebrosus* from lower Sonoma County, California, through southwestern British Columbia, and Nussbaum's (1970) *D. copei* in the Columbia River Gorge (both Oregon and Washington sides), the Olympic Peninsula, the Willapa Hills, and the southeastern Washington Cascades (Figure D.5).

Adults are common in many areas, but they are nocturnal and secretive. They can be found in moist coniferous forests under bark, logs, rocks, and wandering about on the forest floor (Beatty et al. 1991). During the breeding season they can be found in or near streams and are also resident in talus slopes associated with road cuts throughout most of their range (Nussbaum et al. 1983, Stebbins 1985, Beatty et al. 1991 pers. obser.). Gomez (1992) found Pacific giant salamanders to be most abundant in riparian areas of mature and old-growth forests as compared to upland sites and young and deciduous forests.

Ecology and management.—Larval giant salamanders feed upon a wide variety of aquatic invertebrates and vertebrates (fish, tadpoles, and conspecifics). Predators on larval forms include fishes, weasels, water shrews, and other giant salamanders. Metamorphic individuals have a reputation for being voracious predators. Stomach analyses have showed that they eat terrestrial invertebrates as well as many kinds of vertebrates (snakes, shrews, and birds) (Metter 1963, Nussbaum et al. 1983, Stebbins 1985).

The effects of logging on stream amphibians has been examined by Corn and Bury (1989). They were able to compare densities of salamanders in logged versus unlogged reaches of streams in areas where stream gradients were high and low. The major effects of logging on habitats of these salamanders seems most severe on low gradient reaches of streams that have been disturbed by timber harvest. Disturbance adjacent to lower gradient areas in the stream or along the banks of higher gradient riparian areas allows the deposition of sediment, which fills cracks and crevices in lower reaches, making the habitat unsuitable. A second effect, apparently limited to cut over areas on higher gradient streams is the enhancement of population densities owing to the increased primary and herbivore production which canopy opening allows (Hawkins et al. 1983). This may be a short term improvement as no long term published studies dealing with population dynamics exist.

Olympic Salamanders (Rhyacotriton spp.)

Range and habitat.—This group of species is the sole member of the subfamily Rhyacotritoninae and ranges from the Olympic Peninsula of northwestern Washington southward to Mendocino, California in humid coastal forests, entirely west of the crest of the Cascade Mountains (Anderson 1968; Figure D.4). This group is comprised of four different species which is soon to be revised by Good and his coworkers.

These salamanders are found in and near small, rapidly flowing, well-shaded and permanent streams with clear, cold (usually 6° to 10° C) water (Stebbins 1951). They are seldom more than 1 meter from free-running water (Nussbaum and Tait 1977). Small cold (8° to 12° C in summer) streams with water seeping through moss-covered gravel are preferred habitats. Larvae occur in small mountain streams, spring heads and seepages from sea level to about 1,200 meters (Nussbaum et al. 1983).

Ecology and management.—Olympic salamanders apparently require fairly low ambient temperatures. Adults may occasionally be found under objects a

few meters from water after heavy rains, but this is unusual (Nussbaum et al. 1983). Corn and Bury (1989) compared four species of aquatic amphibians in 23 streams in uncut forests versus those in forests logged 14 to 40 years ago, in the central part of the Oregon Coast Range. The density and biomass of the four species (including *Rhyacotriton* spp.) was significantly higher (2-7X) in the streams of uncut forests, because streams in logged stands generally possessed smaller substrate material, caused by increased sedimentation. Where *Rhyacotriton* spp. occur in and adjacent to small headwater streams, their existence is threatened by timber harvest (Bury and Corn 1988b).

Rhyacotriton spp. are fairly widespread in the Pacific Northwest and are most likely to occur in or adjacent to higher order, cold streams in forested areas. Because of the requirement for permanently cold water in smaller streams, Olympic salamanders are highly susceptible to forest practices that remove canopy cover and elevate water temperatures (Beatty et al. 1991).

Tailed Frog (*Ascaphus truei*)

Distribution and habitat.—Tailed frogs are found west of the crest of the Cascade Range from British Columbia to northwestern California. They are also found in extreme northwestern Oregon, southwestern Washington, northern Idaho, and northwestern Montana. Tailed frogs may be found from sea level to over 2,000 meters. They are usually found near or in fast-flowing, permanent streams in forests. The tadpoles of the tailed frog are unique among northwestern larvae because their oral disc is modified into a sucking organ that enables them to cling to rocks in swift current. In the Oregon Coast Range, Gomez (1992) found tailed frogs to be most abundant in riparian areas of mature- and old-growth forests as compared to upland sites and young and deciduous forests.

Ecology and management.—Adults eat a wide variety of invertebrates including snails, ticks, spiders, mites, and numerous insect species (Nussbaum et al. 1983). Pacific giant salamanders (*Dicamptodon*) are a major predator of *A. truei* tadpoles (Metter 1963, Duellman and Trueb 1986). Populations of *A. truei* may be decimated by natural disasters such as floods that greatly reduce larval populations (Metter 1968).

Ascaphus truei is probably the amphibian most likely to be affected by old-growth habitat loss and habitat destruction. Tailed frogs are closely associated with fast-flowing streams in forested areas and are commonly found within old-growth forests (Bury 1983, Bury and Corn 1988a and 1988b, Raphael 1988, Welsh and Lind 1988, Corn and Bury 1989). Bury (1983) found *A. truei* on undisturbed old-growth sites but none in logged areas. Bury and Corn (1988)b considered *A. truei* to be "sensitive to timber harvest" and that the survival of this species may depend upon protection of cool flowing streams that the species requires for breeding purposes and larval development. In logged stands, tailed frogs are most often found in streams where uncut timber still remains upstream (Corn and Bury 1989). Tailed frogs are likely to be affected by increased water temperature that occurs after clear-cutting (Bury and Corn 1988b).

Because of the extreme philopatry and tendency for *A. truei* populations to be extremely disjunct (Daugherty and Sheldon 1982), recolonization after local extinction may take a relatively long time. Therefore, some populations may not recover from habitat destruction.

Summary and Conclusions

As a result of the Secretary of Interior's directive, the Recovery Team considered the needs of other species associated with older forest ecosystems and assessed the benefits to others species from various recovery options. The Other Species and Ecocystems Committee emphasized species that were listed federally as threatened or endangered, candidates for federal listing, state sensitive or species of special concern, and those associated with older forests. We assembled a list of 364 species of plants and animals that meet the above criteria and occur within the range of the northern spotted owl. We also provided descriptions of older forest and riparian ecosystems, unique food webs of older forests, the use of the spotted owl as an indicator species, and the biology of spotted owl prey. In this section, we present an overview of the committee's work and accomplishments and how we were able to benefit other species with the owl recovery plan; this section summarizes information in Chapter V as well as this appendix.

The list of 364 species is comprised of 23 species of birds, 18 mammals, 26 amphibians and reptiles, 28 fish, 58 molluscs, 59 arthropods, 144 vascular plants, and 8 fungi and lichens. Five species are listed federally as threatened or endangered (bald eagle, grizzly bear, gray wolf, Sacramento River winter chinook salmon, McDonald's rock cress), and the marbled murrelet and goshawk have been proposed and petitioned for listing, respectively. A total of 155 species was candidates for federal listing, and more than 100 species were listed as threatened or endangered by one or more of the three states or were designated as sensitive or species of special concern. More than 100 species are narrowly or broadly endemic to the Pacific Northwest and 194 are associated with older forests. The large number of species on the list emphasizes the relevance of considering other species in the owl recovery plan.

The committee's work has substantiated the role of riparian ecosystems in coniferous forests of the Pacific Northwest. Of the 364 species that meet our criteria, approximately one third (132) are associated with riparian areas including 28 species of fish, 45 molluscs, 34 arthropods, 12 amphibians, six vascular plants, four mammals, and three birds. The 28 species of fish include approximately 800 stocks that are considered at risk and may become candidates for listing in the future. The numerous riparian associated species plus the number of fish stocks that are considered at risk stresses the importance of riparian areas within the range of the northern owl. As a result, we have provided a brief synopsis of on the ecology and management of riparian ecosystems.

In addition to assembling a list of species for consideration in the owl recovery plan, the committee developed a short list of priority species. The short list of priority species was given the most emphasis in the recovery plan and includes 18 species (bald eagle, marbled murrelet, goshawk, marten, fisher, gray wolf, grizzly bear, Oregon slender salamander, Siskiyou Mountain salamander, Larch Mountain salamander, Del Norte salamander, Olympic salamanders—four species, Pacific giant salamander, Cope's giant salamander, and tailed frog); a large group of riparian associated species; and a small group of species that are preyed upon by the owl (northern flying squirrel, dusky-footed woodrat, bushy-tailed woodrat, deer mouse, western red-backed vole, and red tree vole). Of these species, the marbled murrelet and the numerous fish stocks that are considered at risk were assigned the highest priority. We compiled information on the distribution, biology, and habitat relationships of the priority species and on the ecology of riparian ecosystems. This information was used to influence the design and management of DCAs.

In considering the needs of other species in the recovery plan for the owl, the Recovery Team took advantage of opportunities to benefit other species and ecosystem function without increasing the cost of the plan. This was done by altering the size, shape, and location of DCAs to attain maximum benefit for owls and incorporate other species to the extent possible. Information on other species was used in several ways in the development of the recovery plan. First, in development of the overall strategy for the plan, the team evaluated the overlap between possible owl conservation areas and the geographic ranges of the list of priority species. Second, in developing recommendations for specific management practices in DCAs and the forest matrix surrounding DCAs, the Recovery Team attempted to look beyond the habitat needs of spotted owls. The Recovery Team used the characteristics of older forests, wherever possible, in developing guidelines for management recommendations. This insured that other species would benefit and not be inadvertently harmed.

As a result of these activities, the Recovery Team was able to locate DCAs so that they include approximately 500 locations (nest or occupied sites) of other species, namely 228 occupied murrelet sites, 120 goshawk nest sites, 56 marten locations, 37 fisher locations, and 37 bald eagle nest sites. The greatest benefits to other species were achieved for marbled murrelets in the Oregon Coast Range where 151 occupied sites were included in DCAs. The DCAs also include 2,047 miles of streams with fish stocks that are considered at risk. The greatest benefits to fish stocks were achieved in the Klamath province and the Oregon Coast Range where 696 and 314 miles of stream, respectively, were included in DCAs. Inclusion of streams and of other species sites in DCAs, along with the conservation of older forests for owl habitat, will provide significant benefits to other species within the range of the spotted owl. However, the marbled murrelet and the numerous fish stocks will likely require further conservation efforts in the future by another group, as is the case for most of the other priority species. The conservation needs of arthropods and molluscs are particularly elusive at the present time, because we do not know enough about the geographic distributions or the habitat associations of many of these organisms. In addition, there are many species yet to be described and named within these two groups.

Management guidelines for DCAs were designed to maintain suitable habitat for spotted owls and to develop suitable habitat in stands that are currently unsuitable (see section III.C.2. on silviculture, salvage, and catastrophic risk). These guidelines are written to conserve owl habitat and the characteristics of older forests. As a result, the forests within DCAs will provide habitat for a wide array of other species. For example, the guidelines for salvage of trees after catastrophic events (primarily wind and fire) are designed to provide coarse woody debris (snags and down logs) over a 100-year period. This management will contribute to the habitat requirements of a number of cavity dwellers including cavity-nesting birds and flying squirrels which make extensive use of snags. The recommendations will also promote suitable habitat conditions for marten, salamanders, numerous arthropods, fungi, and small mammals by providing coarse woody debris on the forest floor. The retention of coarse woody debris in riparian areas will provide habitat for fish and other aquatic organisms. In addition, the forest matrix on federal lands will be managed to protect residual habitat areas, reserved pair areas, and managed-pair areas for owls where the DCA network is deficient or there is a risk of catastrophic disturbance. These guidelines will provide habitat for many species that are associated with older forests. Habitat around managed-pair areas will provide habitat for other species if management strategies include long rotations and uneven-aged management with the goal of providing large trees, snags, and coarse woody debris.

Lastly, the Other Species and Ecosystems Committee recommends further surveys, inventory, and research on other species so that their habitat needs can be identified more accurately in the future (see Chapter V). We provided a list of birds, mammals, amphibians, and fishes that were suggested for further review of the status of their populations, and provided a partial list of research topics. Research on arthropods and molluscs is one of the highest priorities. There is a need to understand the responses of all organisms to various silvicultural practices other than clear-cut timber harvests. Information on the ecological requirements of these species will be needed to develop management strategies to sustain populations of all organisms that are well dispersed throughout their range.

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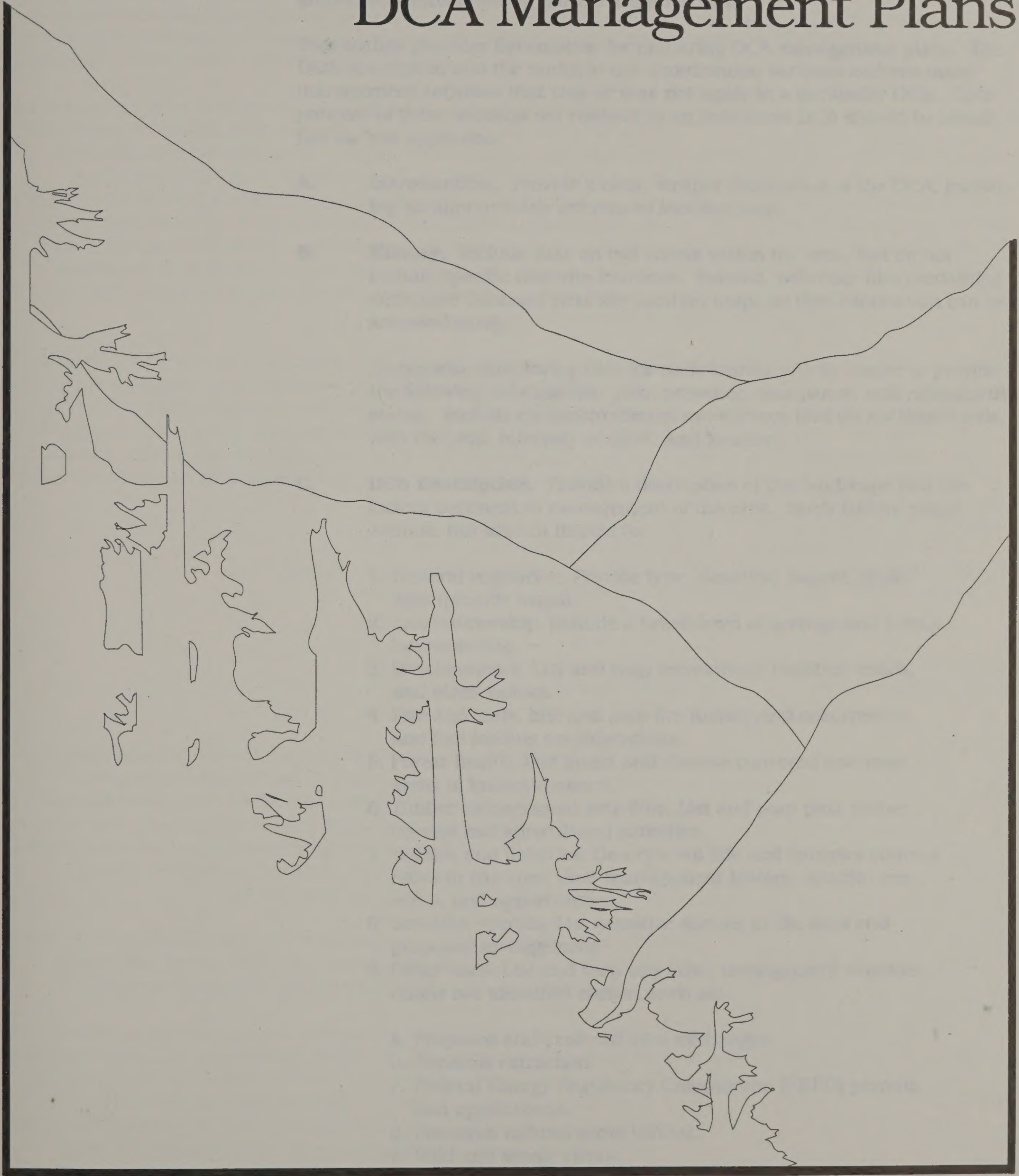
Appendix E

Preparation of DCA Management Plans



E.

Section III.C.2. of the recovery plan discusses proposed management activities within designated conservation areas (DCAs) and provides recommendations related to these activities. Individual DCA management plans will be prepared to address these activities and recommendations, as well as any other on-the-ground concerns affecting northern spotted owls.

This outline provides information for preparing DCA management plans. The DCA description and the multiple-use coordination sections address many management activities that may or may not apply to a particular DCA. Components of these sections not relevant to an individual DCA should be identified as "not applicable."

A. **Introduction.** Provide a clear, written description of the DCA, including an appropriately referenced location map.

B. **History.** Include data on owl status within the area, but do not include specific nest site locations. Instead, reference files containing additional data and nest site location maps so this information can be accessed easily.

Summarize monitoring data for each known activity center to provide the following information: year, presence, occupancy, and reproductive status. Include documentation of owl surveys that do *not* detect owls, with the year, intensity of effort, and location.

C. **DCA Description.** Provide a description of the landscape and the factors pertinent to management of the area. Such factors might include, but are not limited to:

1. General vegetation. Provide type, elevation, aspect, drainages (provide maps).
2. Land ownership. Include a breakdown of acreage and a map by ownership.
3. Developments. List and map recreational facilities, roads, and other factors.
4. Fire and fuels. List and map fire history and occurrences and fuel loading considerations.
5. Forest health. List insect and disease concerns and map areas of known concern.
6. Timber management activities. List and map past timber harvest and silvicultural activities.
7. Wildlife and fisheries. Describe wildlife and fisheries communities in the area, their management history, specific concerns, and opportunities.
8. Sensitive species. List sensitive species in the area and proposed management.
9. Other uses. List and map any other management considerations not identified earlier, such as:

   a. Proposed and expected land exchanges.
   b. Minerals extraction.
   c. Federal Energy Regulatory Commission (FERC) permits and applications.
   d. Research natural areas (RNAs).
   e. Wild and scenic rivers.

f. Wilderness.
g. Livestock grazing.
h. Fuelwood gathering areas.
i. Watershed considerations, including existing and proposed impoundments.

D. DCA Management Objectives. Based on the recovery plan objectives, owl habitat requirements, and existing habitat conditions within the particular DCA, describe site-specific management objectives and desired future conditions, and provide supporting documentation. Objectives are to be specific enough to guide any silvicultural prescriptions and provide direction for planning other management activities.

Examples of the types of management objectives to be included are: 1) identify areas of unsuitable habitat where silvicultural treatment will be used to facilitate the development of suitable habitat, and thus reduce the fragmentation of habitat in the DCA; 2) identify land exchanges that would provide additional suitable habitat; 3) identify roads no longer needed that could be closed or rehabilitated; and 4) identify areas of fuels management concerns within and adjacent to the DCA. Each management objective will include a map showing where the management activity will occur in relation to known owls and habitat.

E. Silviculture. A description of the silvicultural prescriptions that are appropriate for the area will be provided. Prescriptions should be developed by silviculturists and wildlife biologists. They will contain the level of detail necessary for field implementation of those projects that would be scheduled during a 10-year planning period, and will include the following information (easily accessible in permanent files):

1. Stand descriptions.
2. Stand objectives.
3. Silviculture prescriptions and systems.
4. Site preparation treatments.
5. Planting.
6. Release.
7. Hardwood management.
8. Thinning.

F. Risk Assessment. Identify and define the risks to suitable habitat or potentially suitable habitat through an analysis which includes a discussion of the following: wildfire, pathogens, wind, insects, and stand density. Based on the analysis, DCA management plan recommendations will be developed, including prescriptions and implementation plans. These implementation plans will include monitoring strategies and provide for scientific peer review.

To assure effective fuels management within the DCA, significant fuel accumulations will be identified and managed through prescribed burning or other means, as recommended in the recovery plan.

The DCA management plan should take into account conditions on matrix lands adjacent to DCAs. Silviculturists and fire specialists will evaluate these lands to determine whether such conditions pose a fire or windstorm threat to DCA management, and address them in the DCA management plan. The DCA management planning process also should highlight matrix-related concerns to be addressed through

means other than the DCA management plan. For example, it may be necessary to evaluate harvest unit placement and layout to determine the effects of future fuels treatment on owls and owl habitat. Based upon that evaluation, unit location may require modification to meet objectives of owl management. In addition, proposed prescribed burns in the matrix will be evaluated. Seasonal restrictions and limitations on locations of burns will be imposed as appropriate.

G. **Salvage.** The recovery plan includes guidance for salvage of dead trees within the DCAs. Salvage may occur in those instances when it has been determined through review procedures that salvage is necessary to reduce or eliminate an adverse effect on owl habitat. The DCA management plan will specify procedures to be followed consistent with recovery plan recommendations.

H. **Multiple-Use Coordination.** The recovery plan provides recommendations concerning a wide variety of activities that already may occur or may be proposed in DCAs. As applicable, these will be addressed in individual DCA management plans. A proposed or existing activity can proceed if, through an evaluation process, a determination is made that the activity complies with the recommendations contained in a DCA management plan that has been submitted for formal consultation and approved by the U.S. Fish and Wildlife Service.

The recovery plan recommends the evaluation of all proposed activities within a quarter mile of known owl activity centers to determine the effects on owl reproductive success. Activities which would disrupt breeding should be prohibited between March 1 and September 1. Aside from this general restriction, the DCA management plan will tailor management practices according to the existing and potential impacts of proposed activities on owl needs and recovery. As noted in the recovery plan, it may be necessary to modify or eliminate current activities that pose adverse impacts, and impose seasonal or other appropriate restrictions. Consequently, the DCA management plan may require the revision of management guidelines, regulations, or procedures governing particular activities.

The following list includes activities most likely to require attention in DCA management plans. Individual plans will address other concerns, as appropriate to the situation in the specific DCA.

1. Road construction and maintenance.
2. Fuelwood gathering.
3. Mining.
4. Developments.
5. Trail development and maintenance.
6. Land exchanges.
7. Habitat improvement projects.
8. Range facilities.
9. Fire suppression and prevention.
10. Christmas tree sales.
11. Minor forest products.
12. Recreational uses.
13. Research.
14. Rights-of-way, contracted rights, easements.

I. **Monitoring.**

1. Northern spotted owls. Monitoring tasks and informational needs will be defined, consistent with the recovery plan's recommendations (section III.C.6). Monitoring of owls will be particularly important in areas where silviculture and salvage activities are implemented.

2. Habitat. Habitat information should be updated periodically in accordance with the recovery plan's recommendations (section III.C.6). It also should be updated after any significant event (e.g., wildfire, windstorm) that has the potential to alter vegetation. Monitoring of habitat is especially important in areas where silviculture and salvage are practiced. This monitoring would assess (1) whether the activities were implemented properly, and (2) whether they produce the desired effects on habitat. A monitoring plan for these activities is a prerequisite to their implementation.

J. **Coordination.** The management plan must be prepared cooperatively by all landowners and land managers within the DCA. This cooperation is crucial to the success of inventory and monitoring efforts and to the appropriate implementation of silviculture, salvage, and risk reduction activities. Mechanisms to assure ongoing coordination must be identified in the plan.

K. **References.** Include appropriate references as necessary, a list of National Environmental Policy Act (NEPA) documents pertaining to the area, the record of decision, and a brief description of the action for each DCA management plan.

Appendix F

Forest Protection Guidelines for the Northern Spotted Owl

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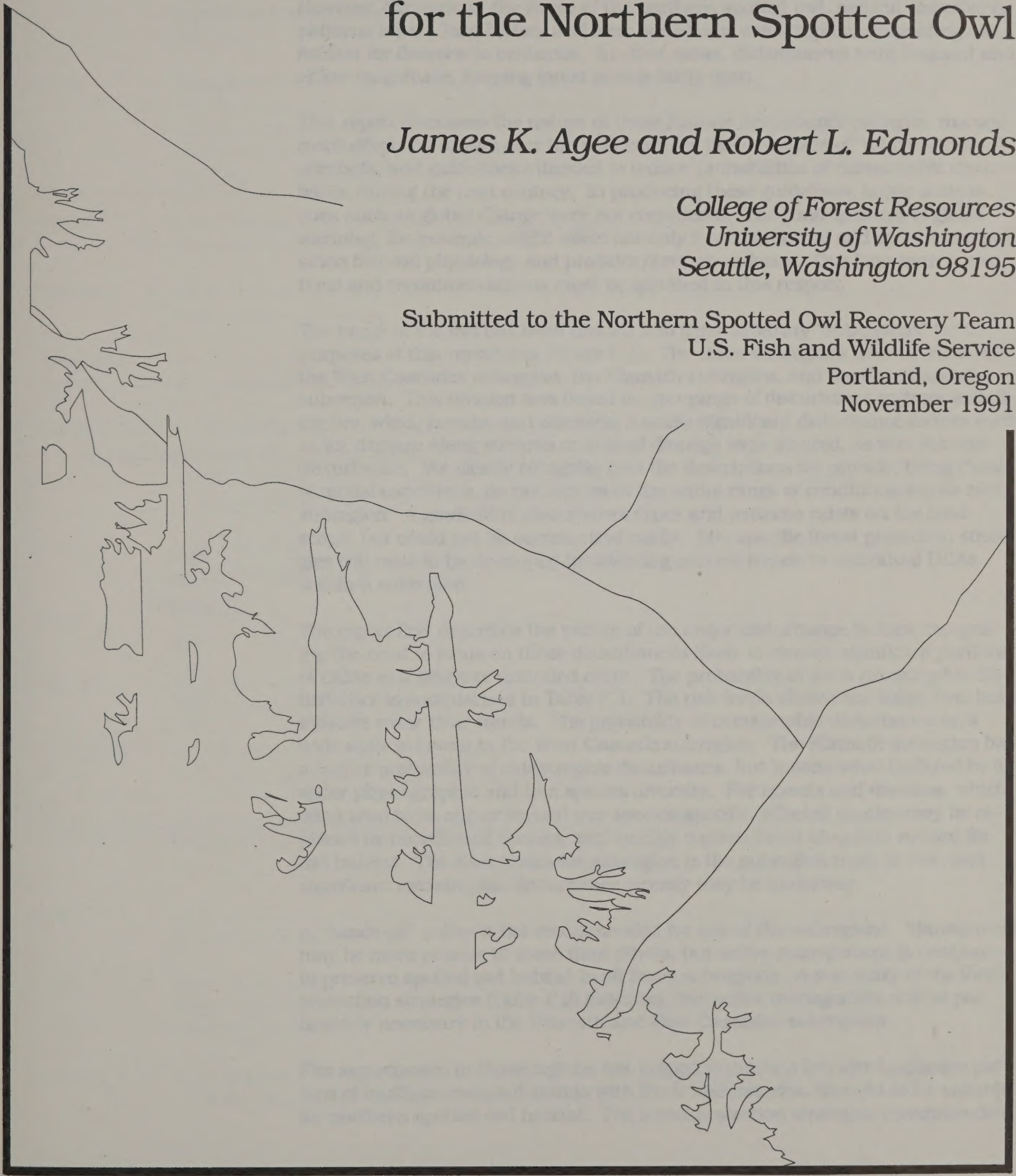
Submitted to the Northern Spotted Owl Recovery Team
U.S. Fish and Wildlife Service
Portland, Oregon
November 1991



Summary

The strategy for protecting the northern spotted owl (*Strix occidentalis* spp. *caurina*) revolves around large management zones called designated conservation areas (DCAs). Most discussion has centered on slowing or stopping timber harvest activities within such areas and leaving them in "protected" status. However, throughout the range of the northern spotted owl, natural disturbance patterns have a long history and were sometimes catastrophic, eliminating owl habitat for decades to centuries. In other areas, disturbances were frequent and of low magnitude, keeping forest stands fairly open.

This report discusses the nature of these historic disturbance patterns, management effects on forests over the past century, likely impacts of "total protection" attempts, and guidelines intended to reduce probabilities of catastrophic disturbance during the next century. In producing these guidelines, larger scale issues such as global change were not considered. The consequences of global warming, for example, might affect not only forest structure and species composition but owl physiology and predator/prey abundance. Our long-term projections and recommendations must be qualified in this respect.

The range of the owl has been divided into three arbitrary "subregions" for the purposes of this report (see Figure F.1). The three subregions defined included the West Cascades subregion, the Klamath subregion, and the East Cascades subregion. This division was based on groupings of disturbance regimes including fire, wind, insects, and diseases. Locally significant disturbance factors such as ice damage along streams or animal damage were ignored, as was volcanic disturbance. We clearly recognize that the descriptions we provide, being those of modal conditions, do not represent the entire range of conditions across each subregion. A gradient of disturbance types and patterns exists on the landscape, but could not be summarized easily. Site-specific forest protection strategies will need to be developed by adapting general trends to individual DCAs within a subregion.

The report first describes the nature of the major disturbance factors, recognizing the need to focus on those disturbances likely to remove significant portions of DCAs in a single or extended event. The probability of such catastrophic disturbance is summarized in Table F.1. The risk levels shown are subjective, but indicate some clear trends. The probability of catastrophic disturbance on a wide scale is lowest in the West Cascade subregion. The Klamath subregion has a higher probability of catastrophic disturbance, but is somewhat buffered by its wider physiographic and tree species diversity. For insects and diseases, which often tend to be one or several tree species-specific, affected species may be replaced by nonaffected species, and quickly replace forest structure needed for owl habitat. The East Cascades subregion is the subregion most at risk, and significant catastrophic disturbance already may be underway.

A "hands-off" policy is not recommended for any of the subregions. Management may be more passive in some than others, but active management is necessary to preserve spotted owl habitat in all three subregions. A summary of the forest protection strategies (Table F.2) indicates that active management will be particularly necessary in the Klamath and East Cascades subregions.

Fire suppression in those regions has helped to create a broader landscape pattern of multiple-canopied stands with thick understories, thought to be suitable for northern spotted owl habitat. The forest protection strategies recommended

here will reduce some of that habitat to more effectively protect the rest. Such forests, in their present condition, are also more likely to be catastrophically disturbed because of higher physiological stress, caused by increased tree density, higher fire hazard, and higher horizontal and vertical fuel continuity.

Recommendations to reduce owl habitat in order to save it may seem a paradox. We believe that such implementation will, in the long run, better protect owl habitat than a more short-sighted attempt to continue total protection. Active management in some areas to reduce the probability of large-scale catastrophic events is the most rational management direction.

Table F.1. Synopsis of catastrophic risk levels from four natural disturbance agents in the three forest subregions.

Disturbance Agent	West Cascades Subregion	Klamath Subregion	East Cascades Subregion
Fire	Low	High	High
Wind	Moderate-Low*	Low**	Low
Insects	Low	Moderate	High
Diseases	Low	Moderate	High

*may be high in areas close to the coast
**may be moderate in areas close to the coast

Table F.2. Summary of risk (bold capital letters) and forest protection guidelines for natural disturbance agents within the three subregions.

Disturbance Agent	**Risk and Forest Protection Guidelines in the West Cascades Subregion**
Fire	**Low** given aggressive fire control strategy with high level of detection and initial attack. Areas often will have poor access. Generally no treatment of slash recommended. Constrain natural fire policies in natural areas where owl habitat is defined as the primary management objective.
Wind	**Moderate** with high risk along coast and less inland. Sitka spruce zone highest risk, along with fragmented forest (areas with high density of patch cuts). Avoid further fragmentation, possibly feather edges of susceptible stands. In windthrow-prone areas where thinning recommended to increase development of suitable owl structure, generally remove more than 30 percent of basal area.
Insects	**Low** Salvage of burned or windthrown timber may be needed in some situations to prevent insect population buildup.
Diseases	**Low** Endemic diseases likely to continue, unlikely to be catastrophic. Some, like mistletoe, may enhance owl habitat.

Disturbance Agent	**Risk and Forest Protection Guidelines in the Klamath Subregion**
Fire	**High** except in higher elevation white and red fir zones and along coast in moist coastal redwood. Need a site-specific fuelbreak zone linked with area treatment (underburning a primary strategy) to reduce potential wildfire severity and extent. This may reduce owl habitat to some extent in treated areas in order to preserve it elsewhere.
Wind	**Low** except along coast. Leave windfirm redwood and Douglas-fir in any coastal thinnings or manipulations; may want to feather edges of existing fragmented forest.
Insects	**Moderate** with some fuel treatment after harvest or wildfire to prevent insect population buildup. Underburning should eventually result in healthier stands with lower stress levels.
Diseases	**Moderate** with disease extent likely to increase with continued fire suppression. Higher tree species diversity tends to buffer impact on owl habitat, however.

Disturbance Agent	**Risk and Forest Protection Guidelines in the East Cascades Subregion**
Fire	**High** will need fuelbreak system plus substantial underburning, particularly in lower elevation habitat, to break up fuel continuity. South aspects a high priority: fewer nest sites there. Subsequent wildfire severity and extent reduced at some cost to existing owl habitat.
Wind	**Low** with some increased wind damage expected if total fire suppression continues and disease continues to increase.
Insects	**High** stand density control is imperative on most sites to reduce stocking and stress on existing stands. Extensive thinning could increase root rot problems. Mortality already occurring in pine.
Diseases	**High** diseases likely to increase in absence of fire. Underburning may help to control some disease by burning out stumps harboring disease organisms.

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I. Introduction

The long-term protection of habitat for the northern spotted owl (*Strix occidentalis* spp. *caurina*) revolves around large protected areas called designated conservation areas (DCAs). This strategy assumes that by protecting fairly large blocks of suitable habitat, and spacing these blocks throughout the range of the species, there is a high probability that the viability of the subspecies will be maintained. A major assumption of this strategy is that the DCAs will perpetually serve as suitable habitat for the spotted owl. A primary threat to the owl to date has been clear-cutting of mature to old-growth stands; the DCA strategy assumes elimination or major reduction in timber removal within DCAs as well as between them. A primary threat in the future for established DCAs will be the probability of damage or destruction by a variety of "natural" disturbance agents: fire, wind, insects, and diseases. The purpose of this report is to describe the nature of these threats, the probability of success of a total protection strategy, and guidelines to increase the probability of successful maintenance of conditions within DCAs suitable for spotted owls in the face of such threats.

Definition of Suitable Habitat

The following description of habitat for the northern spotted owl is abstracted from the proposed critical habitat rules published in the Federal Register on May 6, 1991 (vol. 56, no. 87). The northern spotted owl is known from most of the major types of coniferous forests in the Pacific Northwest. Spotted owls seem to avoid subalpine forests, but have been found as low as 70 feet elevation in the Olympic Mountains and as high as 6,000 feet elevation in California. Spotted owls commonly use Douglas-fir (*Pseudotsuga menziesii*) and mixed-conifer forests in California. In that area habitat tends to be discontinuous in a mosaic pattern. In Washington's coastal forests, the spotted owl is found in forests dominated by Douglas-fir and western hemlock (*Tsuga heterophylla*). At higher elevations spotted owls use Pacific silver fir (*Abies amabilis*), while on the east side of the Cascades, Douglas-fir and grand fir (*Abies grandis*) are used.

The age of a forest is not as important a factor in determining habitat suitability as are vegetational and structural elements. Components of northern spotted owl nesting habitat are: 1) moderate to high canopy closure (60 to 80 percent); a multilayered, multispecies canopy dominated by large (more than 30 inches dbh) overstory trees; 2) a high incidence of large trees with various deformities (e.g., large cavities, broken tops, mistletoe infections, and other evidence of decadence); 3) numerous large snags; 4) large accumulations of fallen trees and woody debris on the ground; and 5) sufficient open space beneath the canopy for owls to fly (Thomas et al. 1990). Old-growth or mixed species stands typically require a minimum of 150 to 200 years to attain these aforementioned attributes. Attributes of breeding and roosting habitat are sometimes found in younger stands, especially those with remnants of the earlier stand that was disturbed by fire, wind storms, inefficient logging operations, or highgrading. However, nearly all nest and roost sites are found in the portions of these stands with the oldest components. In the Oregon Coast Ranges, Oregon Cascades, Washington Cascades, Olympic Peninsula, and Klamath Province, owls use old forests more than expected for foraging and roosting.

Selection of Forest Types

At the time this report was prepared, fall 1991, a final set of DCAs was not available for analysis. Therefore, we chose three forest "subregions" typical of the range of conditions found in northern spotted owl habitat from Washington through northwestern California. Each subregion has a unique forest species composition, environment, and mix of disturbance agents. Effects of natural disturbance and successful protection scenarios are likely to vary by subregion. This scenario will vary also within subregion, as there is more within-subregion variation than can be adequately represented by the three "modal" scenarios presented in this report.

The first type is the wet-cool type including the whole of the Sitka Spruce (*Picea sitchensis*) Zone and most of the Western Hemlock Zone (Franklin and Dyrness 1973), ranging into the lower Pacific Silver Fir Zone, with less emphasis on the drier plant associations, particularly toward the south within the Western Hemlock Zone. We call this the *West Cascades* subregion (Figure F.1). The second type is the Mixed-Evergreen/Mixed-Conifer Zone of southwestern Oregon/northwestern California, which we call the *Klamath* subregion. The third type is the Grand Fir/Douglas-fir Zone of the eastern Cascades, which we call the *East Cascades* subregion. While these are not wholly homogeneous subregions, they encompass the range of variability expected in northern spotted owl habitat protection scenarios.

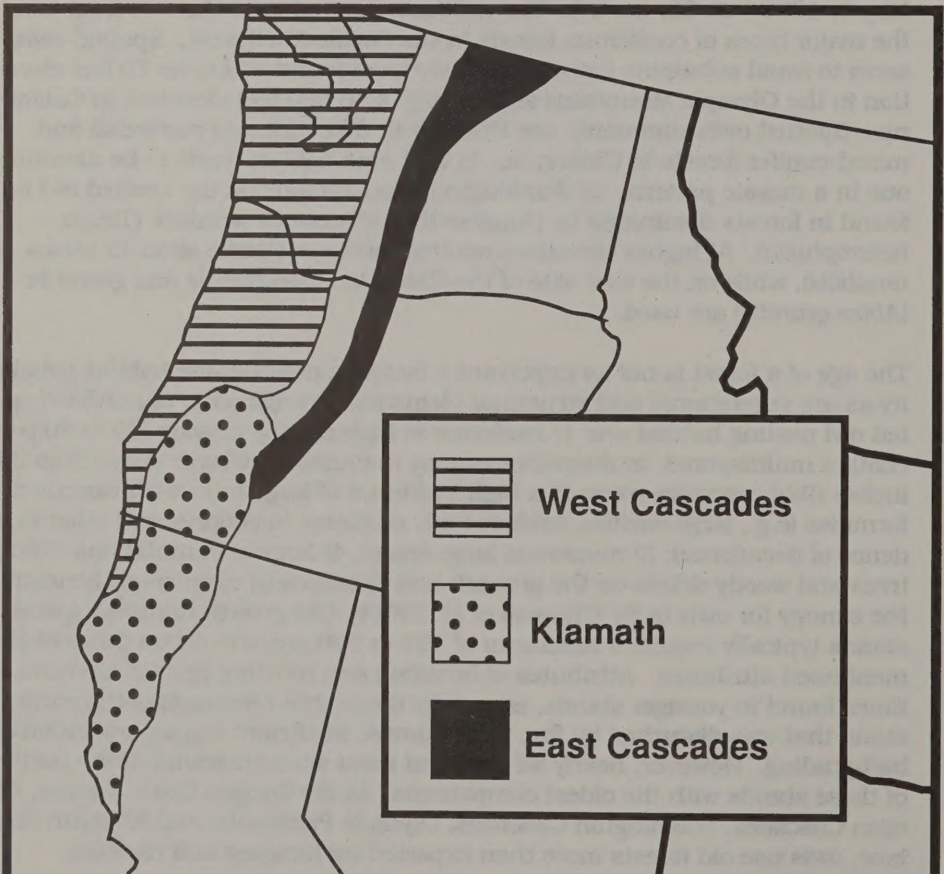


Figure F.1. *General geographical range of the three subregions defined in this report. Where subregions meet, there is an overlap that is not represented in this figure.*

Table F.3. Major tree species in the region and their relative importance by subregion.

Species	West Cascades		Klamath		East Cascades	
	Sitka Spruce Zone	Western Hemlock Zone	Mixed Conifer Zone	Mixed Evergreen Zone	Douglas-fir Zone	Grand Fir Zone
Sitka spruce	M	m	—	—	—	—
Western redcedar	M	M	—	—	—	—
Western hemlock	M	M	—	—	—	—
Douglas-fir	m	M	M	M	M	M
Pacific silver fir	—	m	—	—	—	—
Pacific madrone	m	m	M	—	—	—
Tanoak	—	—	M	—	—	—
White/grand fir	—	—	M	m	m	M
Ponderosa pine	—	—	M	M	M	m
Lodgepole pine	—	—	m	—	m	M
Western larch	—	—	—	—	—	M

M = major species m = minor species
Note: Not all species in a type are listed. Some that are listed above may be classed as absent (—) because they are present in special environments only (e.g., riparian) or are not widely distributed across the type.
(adapted from Franklin and Dyrness 1973)

Characteristics of Forest Types of the Three Subregions

The general characteristics of the forest types of the Pacific Northwest are well described in Franklin and Dyrness (1973). A skeletal description of the subregions included in this report is made to provide a brief context for the sections of the report to follow. In the West Cascades subregion, northern spotted owls are found in the Sitka Spruce Zone, the Western Hemlock Zone, and into the Pacific Silver Fir Zone, the latter of which is not fully described here, although some owls may live in these forests. The Sitka Spruce Zone is a narrow coastal strip normally a few miles in width, except where it extends up river valleys. Its proximity to the ocean and summer fogs, and presence of Sitka spruce (Table F.3), differentiate this zone from the Western Hemlock Zone, which has many of the same species.

The Western Hemlock Zone (Table F.3) occurs over much of the lowlands west of the Cascade Mountains, and is often dominated by Douglas-fir as the major seral tree species; western hemlock is commonly found in all canopy layers in old-growth forest. Its upper boundary with the Pacific Silver Fir Zone often corresponds to the line of perennial snowpack in winter months. The portion of the Pacific Silver Fir Zone which contains owl habitat also has Douglas-fir as a seral species, but increasingly Pacific silver fir replaces western hemlock as the late successional tree dominant. The wetter plant associations may receive up to 160 inches of annual precipitation, and the driest plant associations may

receive as little as 25 inches. Discussion of disturbance and forest protection for this zone is most applicable to the wetter plant associations (those with more than about 60 inches of annual precipitation). The drier western hemlock plant associations are on an environmental gradient toward the Mixed-Conifer Zone discussed for the Klamath subregion, environmentally if not geographically.

The Klamath subregion forests include those of the Mixed-Evergreen Zone, the Mixed-Conifer Zone, and the White Fir Zone, the latter of which is a moist and cool transition normally above either of the other two zones in southern Oregon and northern California. Douglas-fir is a common dominant in both forest types. In the Mixed-Conifer Zone, ponderosa pine, white or grand fir, sugar pine (*Pinus lambertiana*) or incense-cedar (*Calocedrus decurrens*) may be codominants. In the Mixed-Evergreen Zone, madrone (*Arbutus menziesii*), tanoak (*Lithocarpus densiflorus*), black oak (*Quercus kelloggii*), and canyon live oak (*Quercus chrysolepis*) are common lower canopy dominants, while in the Mixed-Conifer Zone, white fir is commonly the lower canopy dominant.

The East Cascades subregion includes the mid-elevation Douglas-fir and Grand Fir Zones sandwiched between higher elevation subalpine forest and lower elevation ponderosa pine forests. In some locations, particularly northern Washington, the Grand Fir Zone is absent. Douglas-fir tends to be a canopy dominant, sometimes with western larch (*Larix occidentalis*) and/or ponderosa pine (*Pinus ponderosa*). Grand fir in the Grand Fir Zone, and Douglas-fir in the Douglas-fir Zone, are the most shade-tolerant species and may be well represented in the lower canopy layers.

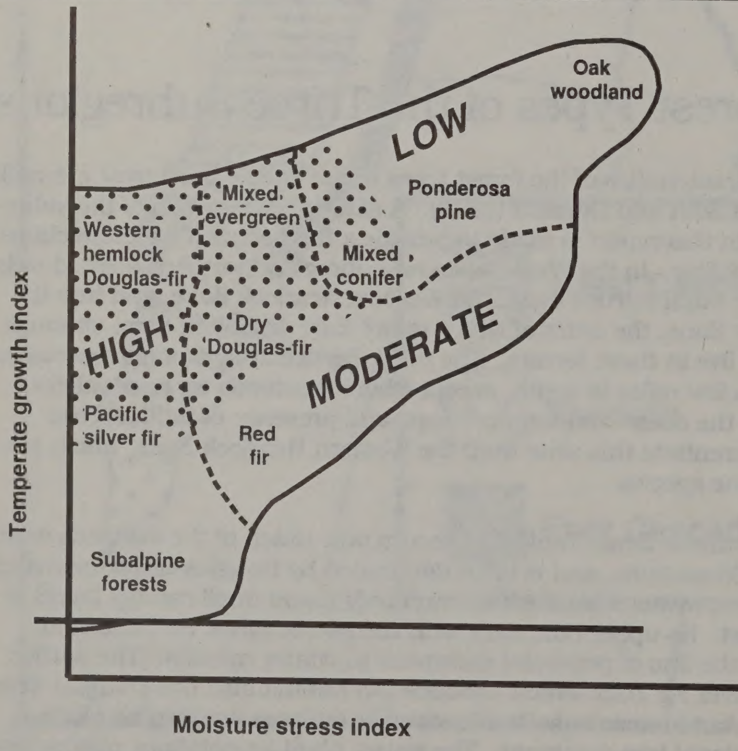


Figure F.2. *Fire severity regimes of the Pacific Northwest. Major forest types are ordinated on temperature and moisture axes, and then defined as high, moderate, or low severity regimes. The types enclosed by the stippled pattern are those where the northern spotted owl is found.*

II. Major Natural Disturbance Factors of the Region

Traditional theories of disturbance in ecosystems have held that disturbance must be a major event and must originate outside the ecosystem (i.e., be exogenous) (White 1979). We now embrace a much broader concept of disturbance, recognizing a disturbance gradient from minor to major and the endogenous component of many disturbances (due either to biotic agents or ecosystem states that encourage disturbance to occur). As we accept this broader concept, we thereby create a fuzzier image of disturbance.

Disturbance is a difficult word to define. A simple definition is to "interrupt" or "break up a quiet or settled order." Forest ecosystems, we know, are not "quiet or settled orders," but when do the natural, normal rhythms of the system oscillate to a point where they become "abnormal"? There is no easy answer, but White and Pickett (1985) suggest that disturbance can be defined as ". . . any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment." It may be characterized by such descriptors as frequency, magnitude, extent, predictability, synergism, and timing (White and Pickett 1985). It may include processes such as forest fire, wind, insect, and disease outbreaks, ice and freeze damage, landslides, floods, and others. Disturbance need not be either a disaster or a catastrophe.

In Pacific Northwest forests, the primary disturbance factors of concern in DCA protection are fire, wind, insects, and disease. This report therefore focuses on these and omits the minor disturbance factors that normally are of limited extent and major disturbance factors such as volcanoes.

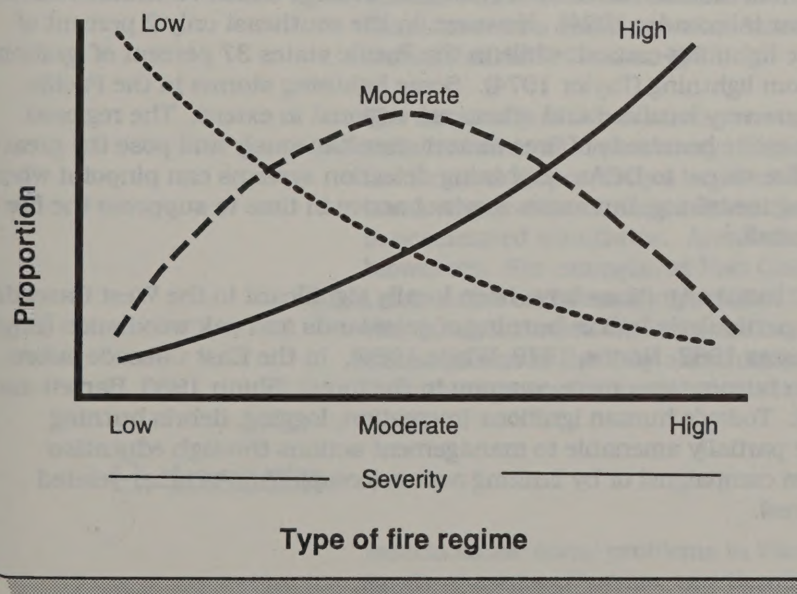


Figure F.3. *A range of fire severity levels is found within each fire regime depicted in Figure F.2. The proportion of the various fire severity levels are shown by the lines of the graph. As fire severity regimes move on the left-to-right gradient from low to high, the proportion of low severity fires decrease while high severity fires increase. Moderate severity fires peak in the moderate severity regime, which is the most complex fire regime in terms of fire effects.*

A. Fire

The combination and interaction of fire frequency, intensity, and extent that occur in an ecosystem are known as a fire regime. The fire regimes of Pacific Northwest forests span a wide gradient of variation (Agee 1981). Natural fire regimes ranged from infrequent (hundreds of years) stand replacement fires, to very frequent (several years) low-intensity surface fires that had little effect on the canopy trees. The fire regime is a way to synthesize the effects of fire by combining many of the descriptors listed earlier. Although fire regimes can be described on the basis of characters of the disturbance itself (Heinselman 1981), or character of the vegetation (Davis et al. 1980), another way is by defining the fire regime on the basis of fire effects, or severity (Agee 1990). The system using fire severity is defined in terms of fire effects on dominant tree species, and works well for application to owl habitat. For the Pacific Northwest, three levels of fire severity are recognized (Figure F.2): high, moderate, and low. Northern spotted owls occur in forests subjected to all three fire severity types.

A high severity fire is one that topkills most of the vegetation in the stand (70 to 80 percent plus of the basal area); a moderate severity fire topkills 20 to 70 percent; and a low severity fire topkills less than 20 percent of the basal area. Fire, in a silvicultural sense, tends to thin from below, first taking smaller trees and/or those less fire-resistant (thin-barked, for example). It must be recognized that each regime is defined on the basis of the modal severity but that fires of other severity levels are likely to occur as well (Figure F.3). The most complex fire regimes are the moderate ones because of the mix of expected fire severities, while the low and high fire severity regimes are generally more predictable. Management activities over decades, such as successful fire protection, can change low or moderate severity fire regimes to moderate to high severity fire regimes. Descriptions of fire regimes in later sections of the report will refer to these severity diagrams.

Within the DCA system lightning will be the largest single source of ignition for fires. Lightning is the primary source of forest fires worldwide, with as many as 44,000 thunderstorms occurring daily over the earth (Trewartha 1968). Thunderstorm activity is relatively mild in the Pacific Northwest. While Portland, Oregon, and Tacoma, Washington, average 5 thunderstorm days per year, and Baker, Oregon, and Walla Walla, Washington, average 10 to 15, southeastern areas such as Mobile, Alabama, average about 75 thunderstorm days per year (Alexander 1924). However, in the southeast only 2 percent of wildfires are lightning-caused, while in the Pacific states 37 percent of ignitions originate from lightning (Taylor 1974). Some lightning storms in the Pacific Northwest are very localized and others are regional in extent. The regional storms can ignite hundreds of fires almost simultaneously and pose the greatest type of fire threat to DCAs. Lightning detection systems can pinpoint where the lightning is striking, but crews may not arrive in time to suppress the fire while it is small.

In the past, human ignitions have been locally significant in the West Cascades subregion, particularly Indian burning of grasslands and oak woodlands (Boyd 1986, Teensma 1987, Norton 1979, White 1980). In the East Cascade subregion, Indian burning was more common in the forest (Shinn 1980, Barrett and Arno 1982). Today's human ignitions (recreation, logging, debris burning causes) are partially amenable to management actions through education (Keep Green campaigns) or by limiting access (complete or weather-related road closures).

B. Wind

Most of the information about wind as a disturbance factor is from coastal areas exposed to the Pacific Ocean winds. This area includes the Sitka Spruce Zone, as defined by Franklin and Dyrness (1973), and the adjacent Western Hemlock Zone.

The successional dynamics of these coastal forests are complex because of the types and intensities of disturbances that have interacted with the forests over time. In the absence of disturbance over many centuries, western hemlock and western redcedar (*Thuja plicata*) would dominate the forests of this zone. In the presence of major periodic disturbance such as fire, which removes almost all of the pre-existing stand, Douglas-fir would initially dominate on upland sites and red alder (*Alnus rubra*) would initially dominate on very wet sites, gradually being replaced by hemlock and cedar. Sitka spruce appears to be a "gap-phase" species capable of regenerating in small openings created by windthrow or overstory mortality (Hines 1971). Large fires and blowdowns do occur in spruce-hemlock forests, but smaller scale events may be equally important forces in forest stand development (Harcombe 1986).

Wind appears to have been the most important disturbance factor for the forests of the Sitka Spruce Zone (Ruth and Harris 1979). Most wind-dominated stands have "pit and mound" topography. It is a hummocky ground topography caused by uprooting of tree stems by wind, causing the pit, and subsequent sloughing of the soil material from the base of the uprooted stem, creating the adjacent mound. Usually, the prevailing wind direction creates a pattern of pits on the upwind side and mounds on the downwind (direction of tree fall) side. Most recent windthrown trees also are oriented downwind, although jackstrawing also may occur.

Studies of windthrow in Washington and Oregon suggest most damaging winds are from the southwest (Ruth and Yoder 1953, Steinbrenner and Gessel 1956), or occasionally east (Gratkowski 1956). Blowdown is more important on poorly drained soils (Gratkowski 1956), or where the area is oriented across the direction of the prevailing winds (Moore and McDonald 1974). Species' tolerances to wind may be site-specific. Western hemlock and Pacific silver fir are generally prone to windthrow, western redcedar and Sitka spruce at times may be windfirm, and Douglas-fir has been described as both wind-tolerant and wind-sensitive (Boe 1965, Moore and McDonald 1974, Henderson et al. 1989). Dominants in a stand are often more windfirm than intermediate crown-class trees (Boe 1965, Gordon 1973).

The frequency of winds strong enough to affect stand dynamics cannot be determined with much accuracy. However, topographic situations suggest that flat lands or slopes/ridges exposed to the southwest will be least sheltered. In areas where clear-cutting occurs, the lee side of the patch is most susceptible to accelerated windthrow. Areas sheltered from these winds will suffer less blowdown. For example, at Fort Clatsop near Astoria, Oregon, Merriwether Lewis noted on February 15, 1806: ". . . the S.W. winds are frequently very violent on the coast when we are but little sensible of them at Fort Clatsop, in Consequence of the lofty and thickly timbered fir country which surrounds us from that quarter, from the south to the N. East" (Thwaites 1905).

C. Insects

Insects cause many problems in Pacific Northwest forests and there are thousands of species (Furniss and Carolin 1977). Only a few, however, have major

Table F.4. Important forest insects in the West Cascades, Klamath and East Cascades subregions.

Common Name	Causal Agent	Tree Species
West Cascades Subregion		
DEFOLIATORS		
Western hemlock looper	*Lambdina fiscellaria lugubrosa*	Western hemlock mostly, also associated Sitka spruce, Pacific silver fir and Douglas-fir
Forest tent caterpillar	*Malacosoma disstria*	Alder
TERMINAL MINERS		
Sitka spruce weevil	*Pissodes sitchensis*	Sitka spruce
BARK BEETLES, WEEVILS, AND PINHOLE BORERS		
Douglas-fir beetle	*Dendroctonus pseudotsugae*	Douglas-fir
Hylastes root bark beetle	*Hylastes nigricinus*	Douglas-fir
Root weevil	*Pissodes fasciatus*	Douglas-fir
	Steremnius carinatus	Douglas-fir
Ambrosia beetle	*Platypus* spp., *Gnathotrichus* spp., *Trypodendron* spp.	All conifers
Silver fir beetle	*Pseudohylesinus sericeus*	Pacific silver fir, western hemlock, Douglas-fir
SCALES AND APHIDS		
Cooley spruce gall aphid	*Adelges cooleyi*	Douglas-fir, spruce
CARPENTER ANTS AND WOOD BORERS		
Carpenter ant	*Camponotus pennsylvanicus*	All species
Wood borer	*Buprestids and Cerambycids*	All conifers

continues—

continued—

Common Name	Causal Agent	Tree Species
	Klamath Subregion	
DEFOLIATORS		
Pandora moth	*Coloradia pandora*	Ponderosa pine, sugar pine
Douglas-fir tussock moth	*Orygia pseudotsugata*	Douglas-fir, ponderosa pine
Western spruce budworm	*Choristoneura occidentalis*	Douglas-fir, grand fir
BARK BEETLES		
Douglas-fir beetle	*Dendroctonus pseudotsugae*	Douglas-fir
Mountain pine beetle	*Dendroctonus ponderosae*	Ponderosa, sugar, lodgepole, western white pines
Red turpentine beetle	*Dendroctonus valens*	Ponderosa, lodgepole, sugar, Jeffrey, western white pines
Western pine beetle	*Dendroctonus brevicomis*	Ponderosa pine
Pine engraver beetle	*Ips* spp.	Pines
Fir engraver	*Scolytus ventralis*	True firs
Ambrosia beetle	*Platypus* spp., *Gnathotrichus* spp., *Trypodendron* spp.	All conifers
Flatheaded fir borer	*Melanophila drummondi*	Douglas-fir, true firs
California flat-headed borer	*Melanophila californica*	Jeffrey, sugar, ponderosa pines
SCALES AND APHIDS		
Cooley spruce gall aphid	*Adelges cooleyi*	Douglas-fir, spruce
CARPENTER ANTS and WOOD BORERS		
Carpenter ant	*Camponotus pennsylvanicus*	All species
Wood borer	*Buprestids and Cerambycids*	All conifers

continues—

continued—

Common Name	Causal Agent	Tree Species
East Cascades Subregion		
DEFOLIATORS		
Douglas-fir tussock moth	*Orygia pseudotsugata*	Douglas-fir, ponderosa pine
Western spruce budworm	*Choristoneura occidentalis*	Douglas-fir, grand fir, larch
Larch sawfly	*Pristiphora erichsonii*	Larch
Larch casebearer	*Coleophora laricella*	Larch
TERMINAL MINERS		
Western pine shoot borer	*Eucosma sonomona*	Ponderosa and lodgepole pines
BARK BEETLES AND PINHOLE BÖRERS		
Douglas-fir beetle	*Dendroctonus pseudotsugae*	Douglas-fir
Mountain pine beetle	*Dendroctonus ponderosae*	Ponderosa, white, lodgepole pines
Red turpentine beetle	*Dendroctonus valens*	Pines
Pine engraver beetle	*Ips spp.*	Pines
Fir engraver	*Scolytus ventralis*	True firs
Western pine beetle	*Dendroctonus brevicomis*	Ponderosa pine
Ambrosia beetle	*Platypus spp., Gnathotrichus* spp., *Trypodendron* spp.	All conifers
SCALES AND APHIDS		
Cooley spruce gall aphid	*Adelges cooleyi*	Douglas-fir, spruce
Balsam wooly adelgid	*Adelges piceae*	Grand fir
CARPENTER ANTS AND WOOD BORERS		
Carpenter ant	*Camponotus pennsylvanicus*	All species
Wood borer	*Buprestids and Cerambycids*	All conifers

Source: Furniss and Carolin (1977), Pettinger and Goheen (1982), Holsten et al. (1985), Hagle et al. (1987), Johnson and Lyon (1988), and Partridge et al. (undated).

Insects cause many problems in Pacific Northwest forests and there are thousands of species (Furniss and Carolin 1977). Only a few, however, have major impacts on forests. Insects in Table F.4 are listed according to their activity in forests; e.g., defoliators, terminal miners, bark beetles, aphids and scale insects, and wood borers. Other parts of trees, such as cones, are affected, but these are not included in Table F.4 because they have little impact on forest structure. Note that there are generally fewer insect species having a major impact on forests in the West Cascades subregion than in the other two subregions. Defoliators and bark beetles are important in the East Cascades and Klamath subregions. There, they can create large landscape level disturbance causing tree mortality over thousands of acres. In the West Cascades subregion disturbances are smaller, but occasionally large epidemics of defoliators occur; e.g., the western hemlock looper which had outbreak periods in 1889–1991, 1911–1914, 1929–1932, 1943–1946, and 1961–1963. These outbreaks generally occurred in extensive old-growth hemlock stands (Furniss and Carolin 1977).

Each insect has its own ecological niche and function in western forests and each kind of tree is host to many insects. Some tree species, however, are more attractive to insects than others. For example, Pines and oaks are infested by far more insects than are redwoods and yew. Some insects play a major role in the life cycle and structure of extensive forest areas, such as the western pine beetle in ponderosa pine forests (Furniss and Carolin 1977). With forest harvesting and management many of these insects became destructive and now are controlled artificially.

Most western forest insects are native, although a few, such as the balsam wooly adelgid, have been introduced. Numbers of insects tend to fluctuate widely and some periodically become epidemic, such as the Douglas-fir tussock moth and spruce budworm. A number of bark beetle species also has become epidemic, especially in drier areas. Fire control practices and early forest harvesting practices in the last 75 years are generally thought to have contributed to increases in bark beetle populations by creating populations of stressed trees. Bark beetles tend to cause the highest amounts of insect-related mortality. In healthy ecosystems insects generally remain in small numbers with outbreaks often precipitated by plant stress (e.g., caused by drought, nutrient deficiencies, and air pollution). With predicted global climate change, many plant species could become stressed as temperature and precipitation change beyond their tolerance level (Perry and Borchers 1990). This, plus the fact that insect populations usually grow faster in warmer, drier climates, could lead to large outbreaks. However, climate changes may suppress some insects.

Defoliating insects cause reduced radial growth and height increment, topkilling, and reduced regeneration; they also sometimes kill extensive stands (Swetnam and Lynch 1989). Heavy defoliation by Douglas-fir tussock moth of Douglas-fir and grand fir in north central Idaho caused growth of host species to decrease 75 to 90 percent in 1 year (Brubaker 1978). Normal growth rates returned 3 to 4 years after maximum defoliation, however. Some researchers report increased radial growth of trees after defoliation (Stoszek 1988, Wickman 1990). Lowest levels of defoliation usually are associated with later stages of succession (old-growth) (Stoszek 1988).

Many of the trees killed by bark beetles and defoliators also are being attacked by root diseases and it is sometimes difficult or even impossible to separate the effects of insects and diseases, especially in drier forest types. Snags and down wood from insect-killed trees increase forest-fire hazard but provide important wildlife habitat.

D. Diseases

Forest diseases in the Pacific Northwest are caused mainly by fungi and dwarf mistletoes. Bacteria, viruses, and nematodes also cause diseases but to a minor extent. The major diseases can be classified as foliage diseases, heart rots or bole decays; stem and branch diseases (cankers, rusts, dwarf mistletoes), root rots; and cone and seed diseases. More recently "decline diseases" have been recognized whereby trees tend to decline and slowly die over a period of years. Decline usually occurs in areas where chronic levels of air pollution or drought have induced stress allowing insects and diseases to gain a foothold.

Although the general types of diseases are similar in the West Cascades, Klamath, and East Cascades subregions, the species of fungi and dwarf mistletoes tend to change with the tree species. Some disease organisms have broad host ranges while others have relatively narrow host ranges (Table F.5). There are hundreds of disease organisms in these forests but only the most important

Table F.5. Important forest diseases in the West Cascades, Klamath, and East Cascades subregions.

Common Name	Causal Agent	Tree Species
West Cascades Subregion		
FOLIAGE DISEASES		
Swiss needle cast	*Phaeocryptopus gaumanii*	Douglas-fir
Rhabdocline needle cast	*Rhabdocline pseudotsugae*	Douglas-fir
Brown felt blight	*Herpotrichia nigra*	True firs
Cedar leaf blight	*Didymascella thujina*	Western redcedar
Bynum's blight	*Lophodermella morbida*	Ponderosa pine
ROOT ROTS		
Phellinus root rot	*Phellinus weirii*	Douglas-fir, mountain hemlock most susceptible
Armillaria root disease	*Armillaria ostoyae*	All conifers (Douglas-fir most susceptible)
Annosus root and butt rot	*Heterobasidion annosum*	Western hemlock and true firs most susceptible
Black stain root disease	*Leptographium wageneri*	Douglas-fir most susceptible
Rhizina root rot	*Rhizina undulata*	Douglas-fir

continues—

continued—

Common Name	Causal Agent	Tree Species
HEART ROTS AND DECAYS		
White pocket rot	*Phellinus pini*	Douglas-fir
Annosus root and butt rot	*Heterobasidion annosum*	Western hemlock and true firs most susceptible, Sitka spruce
Velvet top fungus	*Phaeolus schweinitzii*	Douglas-fir, true firs
Sulphur fungus	*Laetoporus sulphureus*	Douglas-fir, spruce
(No common name)	*Poria asiatica*	Western redcedar
Red belt fungus	*Fomes pinicola*	All dead conifers
Pouch fungus	*Cryptoporus volvatus*	Dead conifers
Artists conk	*Ganoderma applanatum*	Hardwoods, conifers
False tinder fungus	*Phellinus ignarius*	Hardwoods
MISTLETOES		
Western hemlock dwarf mistletoe	*Arceuthobium tsugense*	Western hemlock
Oak mistletoe	*Phoradendron* spp.	Oaks
RUSTS		
Western gall rust	*Endocronartium harknessii*	Shore pine, lodgepole pine
White pine blister rust (introduced)	*Cronartium ribicola*	Western white pine
CANKERS		
Phomopsis canker	*Diaporthe lokoyae*	Douglas-fir

Klamath Subregion

Common Name	Causal Agent	Tree Species
FOLIAGE DISEASES		
Elytroderma needle cast	*Elytroderma deformans*	Ponderosa pine
Red band needle disease	*Dothistroma pini*	Ponderosa pine
Lohphodermium complex	*Lophodermium pinastri*	Sugar pine

continues—

continued—

Common Name	Causal Agent	Tree Species
ROOT ROTS		
Phellinus root rot	*Phellinus weirii*	Douglas-fir
Armillaria root disease	*Armillaria ostoyae*	All conifers (Douglas-fir and ponderosa pine most suscept-tible)
Annosus root and butt rot	*Heterobasidion annosum*	Ponderosa pine most susceptible, white fir
Port Orford cedar	*Phytophthora lateralis*	Port Orford cedar
Black stain root disease	*Leptographium wageneri*	Douglas-fir and pines
HEART ROTS AND DECAYS		
White pocket rot	*Phellinus pini*	Douglas-fir, pines, true firs
Velvet top fungus	*Phaeolus schweinitzii*	Douglas-fir, pines, true firs, incense cedar
Pocket dry rot	*Polyporus amarus*	Incense cedar
Sulphur fungus	*Laetoporus sulphureus*	Douglas-fir, true firs, pines
(no common name)	*Poria sequoiae*	Coast redwood
Red belt fungus	*Fomes pinicola*	All dead conifers
Pouch fungus	*Polyporus volvatus*	Dead conifers
MISTLETOES		
Douglas-fir dwarf mistletoe	*Arceuthobium douglasii*	Douglas-fir
Western dwarf mistletoe	*A. campylopodum*	Ponderosa pine
Sugar pine dwarf mistletoe	*A. californicum*	Sugar pine
True fir dwarf mistletoe	*A. abietinum*	White and grand fir
Incense-cedar mistletoe	*Phoradendron juniperinum ssp. libocedri*	Incense cedar
Oak mistletoe	*Phoradendron spp.*	Oaks

continues—

continued—

Common Name	Causal Agent	Tree Species
RUSTS		
Western gall rust	*Endocronartium harknessii*	Shore pine, lodgepole pine
White pine blister rust (introduced)	*Cronartium ribicola*	Western white, sugar pine
Incense cedar rust	*Gymnosporangium libocedri*	Incense cedar
East Cascades Subregion		
FOLIAGE DISEASES		
Elytroderma needle cast	*Elytroderma deformans*	Ponderosa pine
Larch needle blight	*Hypodermella laricis*	Western larch
ROOT ROTS		
Phellinus root rot	*Phellinus weirii*	Douglas-fir, western redcedar
Armillaria root disease	*Armillaria ostoyae*	All conifers (Douglas -fir and ponderosa pine most susceptible)
Annosus root and butt rot	*Heterobasidion annosum*	Ponderosa pine most susceptible
Tomentosus root rot	*Inonotus tomentosus*	True firs, ponderosa and lodgepole pines
HEART ROTS AND DECAYS		
White pocket rot	*Phellinus pini*	Douglas-fir, pines, true firs, larch, hemlock, western redcedar
Velvet top fungus	*Phaeolus schweinitzii*	Douglas-fir, pines, true firs, larch, western redcedar
Sulphur fungus	*Laetoporus sulphureus*	Douglas-fir, true firs, pines, larch, western redcedar
Indian paint fungus	*Echinodontium tinctorium*	True firs, hemlock, western redcedar
Quinine conk	*Fomitopsis officinalis*	Douglas-fir, pines, larch

continues—

continued—

Common Name	Causal Agent	Tree Species
Red belt fungus	*Fomes pinicola*	All dead conifers
Pouch fungus	*Cryptoporus volvatus*	Dead conifers, esp. ponderosa and lodgepole pines
MISTLETOES		
Douglas-fir dwarf mistletoe	*Arceuthobium douglasii*	Douglas-fir
Western dwarf mistletoe	*A. campylopodum*	Ponderosa pine
Lodgepole pine dwarf mistletoe	*A. americanum*	Lodgepole pine
Larch dwarf mistletoe	*A. laricis*	Western larch
Oak mistletoe	*Phoradendron sp.*	Oaks
Incense-cedar mistletoe	*Phoradendron juniperinum* ssp. *libocedri*	Incense cedar
RUSTS		
Western gall rust	*Endocronartium harknessii*	Shore pine, lodgepole pine
Comandra blister rust	*Cronartium comandrae*	Ponderosa pine, lodgepole pine
White pine blister rust	*Cronartium ribicola* (introduced)	Western white pine

Source: Bega(1979), Boyce (1961), Hadfield et al. (1986), Hagel et al. (1987), Hepting (1971), Holsten et al. (1985), Partridge et al. (undated), Pettinger (1982), Sinclair et al. (1987), and USDA Forest Service (1983).

organisms; i.e., those likely to strongly influence the structure of forests, are listed in Table F.5. Most of the diseases in the region are native. White pine blister rust, however, is introduced and has had a major impact on populations of five-needled pines.

The type of disease typically changes as forest succession proceeds (Table F.6). Root rots tend to be more important in the early stages of succession while heart rots and other decays and dwarf mistletoes tend to be more important in later stages of succession, especially in old-growth forests. Root rots, however, can be an important disturbance in old-growth forests; e.g., *Phellinus weirii* in 150- to 250-year-old mountain hemlock stands in central Oregon (Waring et al. 1987). Franklin et al. (1987) implicate diseases as a major cause of tree mortality in old-growth forests, especially in the West Cascades subregion. They are probably a more important cause of mortality than insects in this subregion.

Diseases constitute a major disturbance factor in natural forests. They create habitat for wildlife and contribute to species diversity. Wildlife habitat is created through tree mortality resulting in standing dead snags and down logs. In addition, cavities can be easily excavated by animals in living trees with rot. Decay in tree tops also may cause tops to fall during wind storms, creating nest sites. Furthermore, parasites such as dwarf mistletoes create witches' brooms and other abnormal branching patterns that also may be suitable for nest sites for owls. Dwarf mistletoe-infected trees may be extremely important sites for spotted owls in the East Cascades subregion. In the West Cascades subregion spotted owls may utilize dwarf mistletoe-infected trees as well as trees with cavities created by disease organisms. Dwarf mistletoes also may affect fire behavior and species succession in some drier ecosystems (Wicker and Leaphart 1976).

As a result of tree mortality, gaps are commonly created in forests. These gaps provide more light to the forest floor and encourage light-loving understory plants. Thus, species and structural diversity is increased and the rate of forest succession is increased. Generally, the scale of disease disturbance; e.g., infection centers in stands, is considerably smaller than the landscape-size disturbances created by bark beetles or defoliators. Most of the fungi causing diseases are decomposer organisms in natural ecosystems. In this role they decompose organic matter, including woody debris, and cycle nutrients (Waring et al. 1987).

Table F.6. Changes in causes and rates of tree mortality during forest successional stages in the Douglas-fir region of the Pacific Northwest.

	Stage				
	Prevegetative Closure	Full Vegetative Cover	Closed Tree Canopy	Mature Forest	Old Forest
Approximate period (years)	0 to 5	5 to 20	20 to 100	100 to 200	>200
Mortality rate	Very high	High	High to medium	Medium to low	Medium to low
Typical mortality causes	Environmental stress, predation, pathogens	Interspecific competition, environmental stress, pathogens, predation	Intraspecific competition, pathogens, wind	Pathogens, wind, competition	Wind, pathogens, physiological disorders

Source: Franklin et al. (1987).

III. Forest Protection in the West Cascades Subregion

A. The Natural History of Disturbance

Fire

In the moist Douglas-fir forests of the Coast Range of Oregon, the Washington Cascades, and the Olympics, fire return intervals are long (Fahnestock and Agee 1983) and most forests are first-generation post-fire forests less than 750 years old. This would suggest a fire return interval somewhat less than 750 years. The fire cycle model of Agee and Flewelling (1983), which is based on climate, could not reproduce a natural fire rotation (essentially a fire cycle) less than 3,500 years using 20th Century climate patterns, and even with significant alteration in climate input to the model, fire return intervals could only be brought down to about 900 years. They suggest that perhaps much larger than average events may have occurred in the past (also suggested by Henderson and Peter 1981, for the southeastern Olympics) as a result of short-term but very extreme changes in two or more of the climate parameters that drive the model.

Large fires have occurred in the historic past (Morris 1934) but our knowledge of old-growth forest establishment dates is so weak as to preclude firm hypotheses about disturbance pulses of the presettlement past. The forests around Mt. Rainier appear to have had a major fire event about 750 years ago (Hemstrom and Franklin 1982) and similar aged stands have been identified in the southern and western Olympics (Agee personal observation). A series of about 650-year-old and/or 450- to 500-year-old fires is apparent from the data of Henderson and Peter (1981) in the southern Olympics; Franklin and Hemstrom (1981) and Yamaguchi (1986) in the southern Washington Cascades; and Huff (1984) and legend (Quinault Natural Resources 1983) in the western Olympics. Although forest age-class data are sparse, these are also times of sunspot minima identified by Stuiver and Quay (1980), using tree-ring analysis of carbon-14 activity. If large fire events are associated with these periods of general global cooling, they may represent periods where altered synoptic weather patterns, particularly during the growing season, contained higher lightning frequency and foehn (east) wind patterns.

In moist Douglas-fir forests, long early seral tree recruitment (e.g., 75 to 100 years for Douglas-fir) has been documented after disturbance by fire (Franklin and Hemstrom 1981). This pattern is not characteristic of all prehistoric fires. For example, Huff (1984) showed a 60-year recruitment interval for a ca. 1465 fire in the western Olympics, while Yamaguchi (1986) shows that about 95 percent of Douglas-fir was recruited within 40 years after a fire in ca. 1300 near Mount St. Helens. However, even on these sites the regeneration period is decades long and probably represents some regeneration from trees that initially colonized the burn and grew large enough to produce viable seed to help completely restock the stand. Lack of seed source, brush competition, and/or reburns have been identified as factors delaying regeneration on such sites (Franklin and Hemstrom 1981). Patterns of reburns on the Tillamook fire of 1933 at 6-year intervals (1939, 1945, 1951) (Pyne 1982), at Mt. Rainier in the late 19th Century, and at the southern Washington Yacolt burn of 1902 (Gray 1990) are evidence these sites will reburn. High surface fire potential during early succession in Douglas-fir forest was identified by Isaac (1940) as a "vicious cycle" of positive feedback, encouraging rhizomatous bracken fern (*Pteridium aquilinum*); this pattern was quantified by Agee and Huff (1987). Given sufficient sources for reignition (e.g., the original Yacolt and Tillamook

burns and all reburns are thought to have been human-ignited), the reburn hypothesis is likely to be true in certain areas. However, it is not clear whether reburns were a common event prior to European settlement in the moist portion of the Douglas-fir region.

After crown closure, potential surface fire behavior declines, and then gradually increases in the old-growth seral stage (Agee and Huff 1987). Reburns in roughly 100-year-old stands during the late 1400s (Henderson and Peter 1981) may suggest that crown fire behavior independent of surface fuels in these thick-canopied stands may be an additional significant type of fire. Current knowledge is insufficient to tell.

For many years, the pattern of stand replacement fire summarized above was a paradigm of fire for the west side Douglas-fir region. Recent work, particularly in the Oregon Cascades in drier western hemlock plant associations, suggests a higher fire frequency, and different ecological role, for fire in mesic to dry Douglas-fir forest, reinforcing the output of the climate-based fire cycle model (Agee 1991a). A site in the western Oregon Cascades (Stewart 1986) near the H. J. Andrews Experimental Forest regenerated after a stand replacement fire in ca. 1530, but had experienced three partial mortality fires since then, in ca. 1660, 1860, and 1890. Some of these were in the settlement period and probably reflect human-caused fires of that period, but the partial mortality associated with them is significant. Over a broader area several miles to the southeast encompassing similar forest types, Morrison and Swanson (1990) suggest a natural fire rotation of 95 to 145 years over the last 5 centuries, well below that of the moist Douglas-fir forests of Washington. The patchiness of at least some of the fires is illustrated by the fire severity maps in Morrison and Swanson (1990). A similar fire regime was noted by Means (1982) on dry Douglas-fir sites in the western Oregon Cascades and by Agee and Dunwiddie (1984) for dry Douglas-fir forests in Washington's San Juan Islands. Another fire history analysis was completed by Teensma (1987) near the area studied by Morrison and Swanson. Using conservative methods that did not recognize underburns with no resulting regeneration or substantial fire-scarring of trees, Teensma estimated a natural fire rotation of 100 years over the last 5 centuries. If fires of moderate severity are removed from the analysis, a stand-replacement mean fire return interval is 130 to 150 years, suggesting that intense fires are a significant part of the natural fire regime in this area, but that fires of lower severity also occur. Other stands of 500 years age or older exist without much evidence of recurrent fire.

These studies indicate that a variable fire regime with shorter fire return intervals than moist Washington Douglas-fir forests occur in the central Oregon Cascades, and in other mesic to dry Douglas-fir forests. It is, in a sense, a transitional area to the Klamath subregion in terms of fire history.

Huff (1984) has summarized the species response to disturbance regimes for moist Douglas-fir forests. If fire is absent for 700 to 1,000 years on wet sites, Douglas-fir will drop out of the stand, and western hemlock, Pacific silver fir, or western redcedar will be the primary seed source for post-fire regeneration. On sites with fire return intervals in the 300- to 600-year range, well within the longevity of individual Douglas-fir, mixed dominance of Douglas-fir and western hemlock or Pacific silver fir will result from a typically severe stand replacement fire (Figure F.4). By age 200+years, the characteristics of old-growth are almost always present. The Douglas-fir component, having developed after the previous centuries-old fire, provides the large live tree criterion. Both Douglas-fir and the more dense western hemlock begin to supply the large log component as they begin to die from suppression, disease, or windthrow.

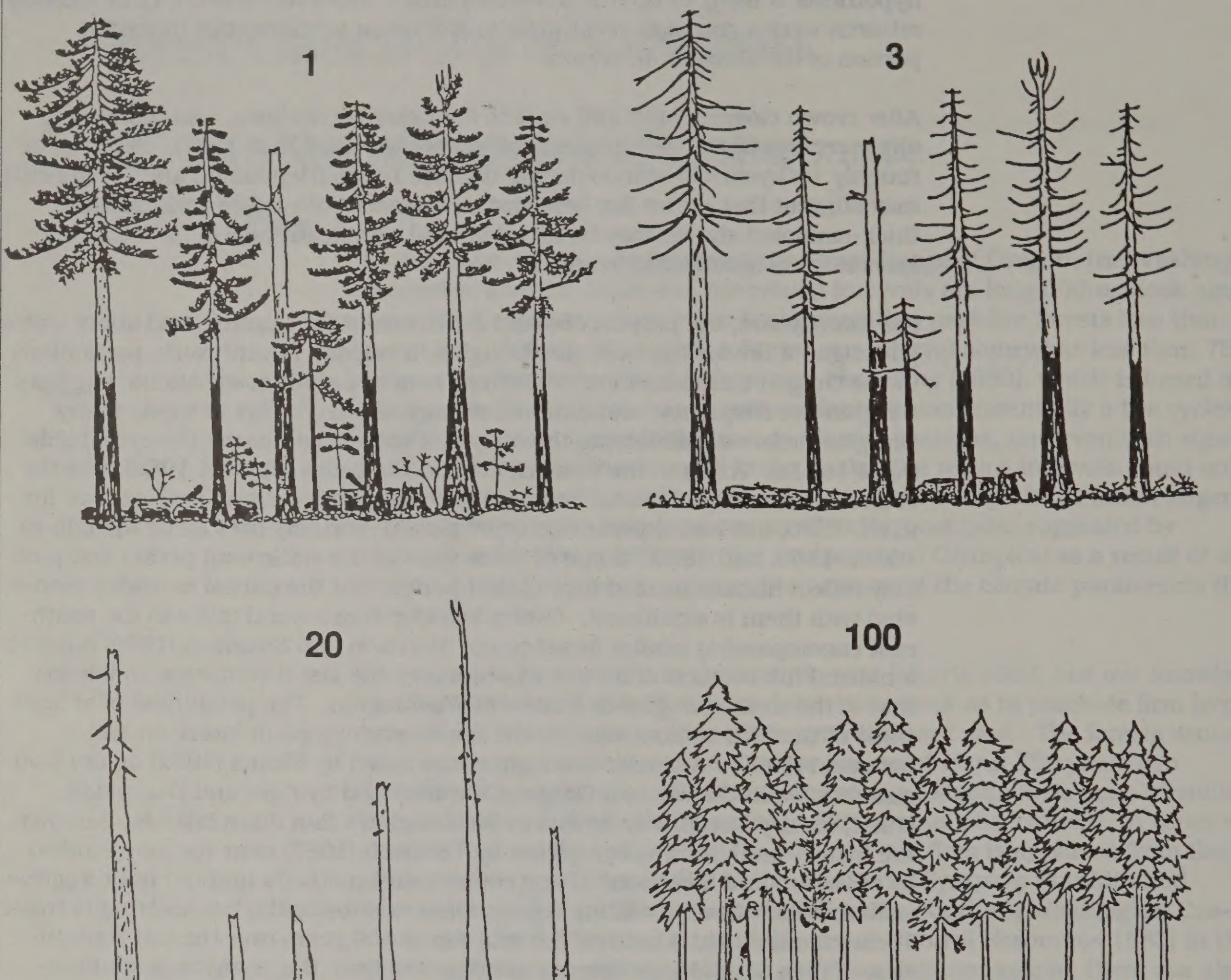


Figure F.4. A stand development sequence for the moist western hemlock/Douglas-fir type. Stand age is shown above each stage, and begins after a total crown scorch fire event. Old-growth character begins between 100 and 200 years and is maximized in the 500-year stand.

Wind

Local situations away from the coast may be associated with substantial wind damage over time. Forests on the lee side of Mt. Rainier, for example, in the White River drainage, appear to have been damaged by winds over past centuries. Trees in the Columbia River gorge area north to at least Mount St. Helens and south to Mt. Hood are "flagged" because of strong easterly winds which desiccate foliage on the upriver sides of the trees. North or east winds, such as occurred in Puget Sound during December 1990, occasionally are associated with substantial windthrow.

At Cascade Head, an exposed headland near Otis, Oregon, Harcombe (1986) found that small-scale events have a larger impact on the forest than large-scale blowdowns, comparing the canopy turnover time of 119 years from small-scale events to 384 years for blowdown from large-scale events (i.e., time for an area equal to the forest area to blow down from either type of disturbance). In fact, small- and large-scale blowdown can occur. Basing long-term windthrow return intervals on 50 years of record, as Harcombe does, is not a very reliable method of prediction for such an episodic disturbance.

In the Olympic Mountains, Henderson et al. (1989) suggest that wind is most important in the coastal zones (Figure F.5). Substantial blowdowns have occurred in 1979 (Hood Canal Storm), 1962 (Columbus Day Storm), and 1921 (Boyce 1929). Stand-level information from ridgeline stands in the western Olympics suggests other wind-associated events in the late 1880s and early 1850s (Agee, unpublished data). Although each event did not affect the entire area, a return interval of about 30 years for major wind disturbances seems to be operating in this area. The Columbus Day Storm also affected other stands throughout the subregion but to a lesser extent and generally in sensitive topographic situations (such as saddles).

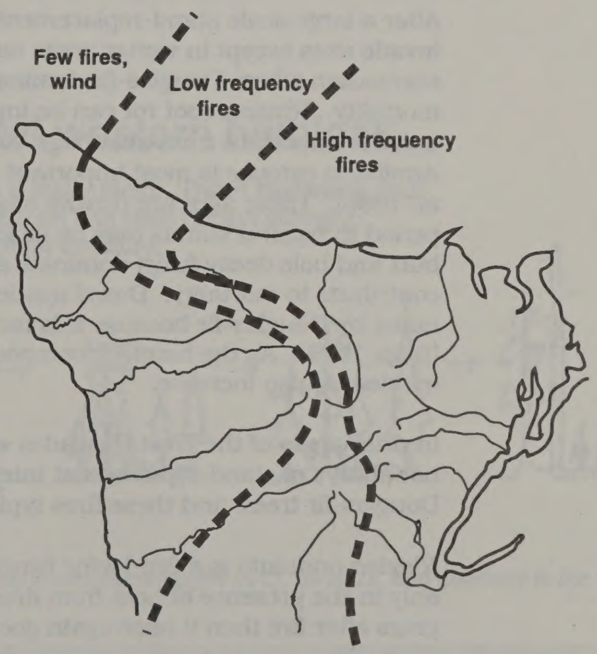


Figure F.5. Map of Olympic Peninsula showing the relationship between groups of environmental zones and forest fire frequency.

Insects

Insects in this subregion usually act as secondary agents of disturbance after major disturbances caused by fire and wind. Insects tend to have less influence in this subregion because physiological stress from drought and other causes is relatively low.

After fire Douglas-fir beetles will attack weakened trees and freshly down trees. Ambrosia beetles will also attack boles of standing dead and down conifers. Trees weakened by root diseases, particularly by *Phellinus weirii*, are very susceptible to Douglas-fir beetle attack.

Occasional outbreaks of the western hemlock looper in extensive old-growth hemlock stands have occurred every 15 to 20 years from the 1890s to the 1960s, but no other insects have caused large scale defoliation. Sitka spruce weevil causes leader deformation in young trees (Furniss and Carolin 1977). Sitka spruce tends to be least impacted by weevils in the fog zone along the coast and up major river valleys. Outside this zone it is commonly attacked by the Sitka spruce weevil.

Diseases

Diseases, especially root rots, stem decays, and dwarf mistletoes, in the West Cascades subregion appear to be a greater agent of disturbance than insects. Foliage diseases, stem cankers, and rusts play a minor role. Diseases appear to occur in a relatively random pattern across the landscape, although some site factors such as moisture no doubt influence disease expression. They have considerable influence on forest succession and biodiversity. Many diseases have specific hosts such as Douglas-fir. Thus, diseases can change species composition in affected stands.

After a large-scale stand-replacement fire (Figure F.6, A-C) Douglas-fir tends to invade sites except in wetter areas near the coast. In the early stages of succession where Douglas-fir dominates, root diseases are important causes of mortality. Rhizina root rot can be important in the seedling stage. *Phellinus weirii* is important from about age 15 to 125 years (Childs 1970) while *Armillaria ostoyae* is most important from about age 5 to 25 years (Hadfield et al. 1986). These ages are relative since in many cases the actual establishment period in natural stands may be as long as 20 years. In old-growth forests, butt and bole decay fungi dominate although root rots are still present and can contribute to mortality. Dwarf mistletoes are not important in forests dominated by Douglas-fir because it is rarely attacked west of the Cascade crest (Bega 1979). As the hemlock component increases with succession, dwarf mistletoes also increase.

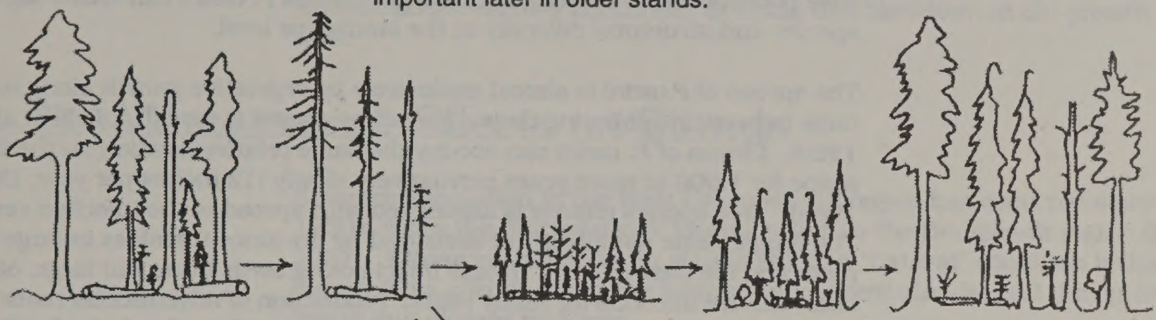
In drier areas of the West Cascades subregion away from the coast, fires are not always of stand-replacement intensity. Such fires may not kill large, old Douglas-fir trees, and these fires typically create uneven-aged stands.

Rhizina undulata is a fire-loving fungus. Dormant spores in the soil germinate only in the presence of heat from fires. The fungus is only active for a few years after fire then it once again goes dormant (Morgan and Driver 1972).

Phellinus weirii tends to create large expanding root rot centers. Northwestern conifers appear to vary in their susceptibility to *P. weirii* (Hadfield et al. 1986). Douglas-fir and true firs are highly susceptible. Western hemlock and Sitka spruce are intermediately susceptible (infected but seldom killed). Western white pine (*Pinus monticola*) and western redcedar are tolerant or resistant. All

Inland Douglas-fir/western hemlock

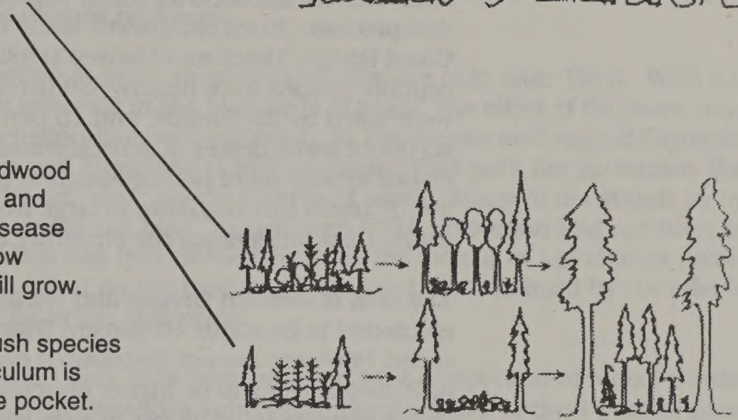
A. Root rots, especially caused by *P.weirii*, kill young Douglas-fir allowing shade tolerant and less disease susceptible western hemlock and western redcedar in the understory to grow in disease pocket. Decay fungi become important later in older stands.



Stand replacement fire

B. Root rots kill young Douglas-fir. Hardwood species, such as red alder, vine maple, and bigleaf maple occupy the pocket. As disease inoculum is reduced Douglas-fir can grow in the pocket. Western hemlock also will grow.

C. Root rots kill young Douglas-fir. Brush species occupy pocket for many years until inoculum is reduced and Douglas-fir can grow in the pocket. Western hemlock also will grow.



Coastal western hemlock

D. Wind is a major factor. Dwarf mistletoes and decay fungi (butt and stem decay) strongly influence forest structure.

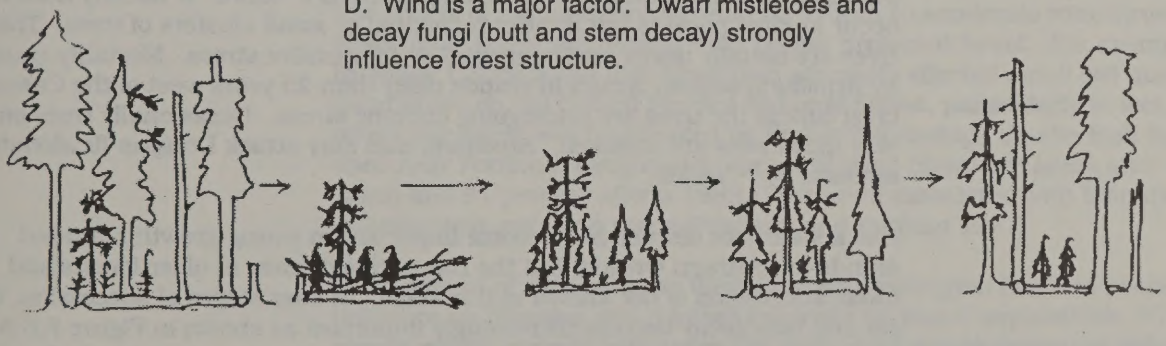


Figure F.6. *Typical theoretical successional sequences involving fire (A-C), wind (D), and diseases in the West Cascades subregion.*

hardwoods are immune. Shade tolerant species in the understory which are less susceptible to *P. weirii*, such as western hemlock, are usually favored thus speeding up succession (Figure F.6A). In some cases, especially in very young stands, hardwoods such as vine maple (*Acer circinatum*), big leaf maple (*Acer macrophyllum*), and red alder (*Alnus rubra*) may establish in *P. weirii* pockets (Figure F.6B). These species are immune to *P. weirii* and this process effectively sets succession back in time. Brush species also may establish in disease pockets devoid of trees (Figure F.6C). Thus *P. weirii* can create significant species and structural diversity at the landscape level.

The spread of *P.weirii* is almost exclusively by vegetative growth along root contacts between neighboring trees. Spread by spores is rare (Hadfield et al. 1986). Clones of *P. weirii* can occupy the same relative location on the landscape for 1,000 or more years moving very slowly (12 inches per year; Dickman 1984). Tree species change is associated with spread of the infection center. The fungal clone usually is not destroyed by fire since it resides in large woody roots and the base of trees. It also infects old-growth trees, but large, old trees often survive infection for many years. Production of adventitious roots assists this process. In an old-growth stand dominated by Douglas-fir in the Oregon Coast Range, Tkacz and Hansen (1982) estimated that 19 percent of the susceptible species were healthy, 30 percent were live and infected, 36 percent were killed by the fungus, and 15 percent were killed by other causes. There is no doubt some degree of genetic resistance to the fungus exists and some clones appear more pathogenic than others (Driver and others 1972). After fire, *P. weirii* can stay alive in large woody root systems for as long as 100 years, thus influencing the structure of the post-fire stand.

The area of western Oregon and Washington heavily infected by *P. weirii* is estimated to be about 10 percent (Hansen and Goheen 1989). Clones of *P. weirii*, however, are not distributed evenly across the landscape. The incidence of *P. weirii* seems to be higher on moisture and/or nutrient stressed sites. Incidence appears to be higher in sites with dry gravelly soils and or lower rainfall and ridges and upper slopes (Kastner 1991). Disease incidence is not strongly related to aspect. *P. weirii* incidence seems to be particularly high in the Puget Sound region, the Cascade Mountains foothills, the Oregon Coast range, and mountain hemlock (*Tsuga mertensiana*) forests of the Oregon Cascades.

Armillaria ostoyae attacks a wider range of conifers than *P. weirii*, but in this subregion it is not thought to be as important as *P. weirii*. It usually does not occur in large pockets but attacks individual or small clusters of trees. These trees are usually under environmental or competitive stress. Mortality caused by *Armillaria* seldom occurs in stands older than 25 years west of the Cascade crest unless the trees are undergoing extreme stress. Occasionally trees on very moist sites are attacked. *Armillaria* also may attack Douglas-fir already stressed by *P. weirii*.

Black stain root disease has become important in young-growth managed stands in southern Oregon, but the role of this disease in older forests and forest succession is not known at this stage. In later stages of succession, butt rot and bole decay become increasingly important as shown in Figure F.6 A-C. Dwarf mistletoe is also important in areas with a lot of western hemlock.

In coastal areas where western hemlock and Sitka spruce dominate, and where wind is the primary disturbance rather than fire, root rots do not seem to be as important as they are in Douglas-fir dominated forests (Figure F.6D). In coastal forests decay fungi tend to be the dominant disturbance agents along with hemlock dwarf mistletoe. *Heterobasidion annosum* is the dominant disease organism in western hemlock, and commonly acts as butt and root rot. Trees do not seem to develop significant butt rot until they are more than 100

years old. A successional sequence involving dwarf mistletoes and decay fungi in coastal western hemlock forest is shown in Figure F.6D. Dwarf mistletoes strongly affect tree growth and branch habit, but usually do not cause much mortality. Trees in the coastal area tend to grow to large sizes and ages, especially in areas protected from high winds. They typically have considerable defect caused by diseases; large and irregular branches, dead tops and branches, broken tops and snags created by wind, butt rot and decay fungi. *Armillaria* root rot may contribute to whole tree blowdown in old-growth forests.

B. Management Effects on Stands

Stand manipulation in the West Cascades subregion has occurred since the 1850s, when the first extensive logging began in the Douglas-fir region (Ficken 1987). Management effects on stands still in a "natural" condition include fire suppression effects, of cutting pattern on adjacent stands, and the spread of insect and disease problems.

Fire protection in most areas became effective only after 1910. With natural fire return intervals in the hundreds of years, the effect of 80 years of successful fire exclusion has been minimal. In the remote and rugged Olympic Mountains, Agee and Flewelling (1983) estimated that park fire protection this century had "saved" only several thousand acres. Many of the stands in the subregion would not have burned even if fire protection had not been in place, but protection has had subtle effects on the mosaic of age classes present. This subtle effect on the landscape has been overwhelmed by the effects of clear-cutting in the subregion.

Escaped slash fires have been an important component of recent wildfire acreage in the West Cascades subregion. For example, of the 14 major fires in the Mt. Hood National Forest in 1960-75, all started or gained momentum in logging slash (Dell 1977, Deeming 1990). Debris burning was responsible for about 15 percent of wildfire acreage in Oregon and Washington in 1960-80 (Agee 1989). Recent declines in area slash burned, due to air quality restrictions, as well as very large fires from other causes in the 1980s, may likely reduce these percentages in the future.

The effects of management on wind have been to accelerate windthrow along susceptible edges where clear-cuts border protected forest. For example, Ruediger (1985) noted that blowdown adversely affected small owl management areas on the Gifford Pinchot National Forest, particularly in locations where the forest was fragmented by timber harvesting. On the Bull Run watershed near Portland, Oregon, 43 percent of large blowdown areas after a 1973 storm and 81 percent after a 1983 storm were associated with boundaries of existing clear-cuts and roads (Franklin and Forman 1987).

Management of stands in the West Cascades subregion has had considerable influence on diseases and a lesser influence on insect populations. The Sitka spruce weevil strongly influences the successful establishment of Sitka spruce plantations. Populations of the Douglas-fir beetle probably have increased slightly as a result of logging but not usually to epidemic proportions. However, root diseases, especially *Phellinus* root rot, appear to have increased considerably as more and more of the landscape has been converted to young-growth Douglas-fir forests. Stumps created by logging harbor the fungus, allowing it to remain viable (Tkacz and Hansen 1982, Thies 1984). Many young plantations of Douglas-fir are now at risk. Management activities such as thinning seem to have increased the incidence of *Armillaria* and black stain root disease. Reducing the variety of tree species in forests tends to promote

pests (Schowalter 1988). Black stain disease has spread dramatically in Douglas-fir monocultures where nonhost trees are not available to interrupt transmission of the pathogen. Fertilization has been practiced widely but as yet the impact on root diseases seems small. Foliage diseases also appear to have increased but not to epidemic proportions.

C. Likely Outcome of a Total Protection Strategy Over the Next Century

Total protection in the context of this section is defined as "hands-off" management within habitat conservation areas (DCAs) for the next 100 years.

Fire

The West Cascades subregion has the highest probability of a successful fire suppression strategy for DCAs. Mature to old-growth forests have a low surface fire behavior potential (Agee and Huff 1987). Severe fire weather is usually short-lived (Pickford et al. 1980, Huff and Agee 1980). The area of greatest concern is the Columbia Gorge area, where severe east winds can cause fires to move rapidly. DCAs in this area (Gifford Pinchot and Mt. Hood National Forests) still have a high probability of successful protection, but the area has a history of large fires (Gray 1990). While the chance of protection is high, and the probability of a large fire in a DCA is low, over the next 50 to 100 years, portions of some DCAs are likely to burn. There remains the possibility that a large fire complex caused by extremely unusual lightning or east wind events could occur, but the probability of this occurring in the next 50 to 100 years is unknown and likely beyond management control. Global climate change, if it creates more ignition or increases fire behavior potential, may alter fire disturbance patterns.

Wind

Within the coastal Sitka Spruce Zone, large-scale windthrow events are likely to occur several times a century. Within exposed areas (see Figure F.5) substantial blowdown potential exists. The "biological legacy" of green trees left by the 1921 windstorm on the western Olympic Peninsula has allowed rapid habitat recovery to the point that spotted owls now inhabit these stands (North, pers. comm.). It is not clear whether such habitation by owls is recent, or whether it continued through and after the blowdown event, or recovered decades later. In the transitional areas between primarily wind-dominated and primarily fire-dominated areas (see Figure F.5, the Olympic Peninsula), similar windthrow events are likely in forests at the edge of cleared forest or in forest patches interspersed with clear-cut patches. In more inland areas, more localized impacts from wind are likely. Large, unbroken old-growth forests are not likely to suffer severe impacts from wind, while more fragmented areas may suffer severe blowdown (Ruediger 1985, Franklin and Forman 1987).

Insects

Insects have not proved to be a major problem in the West Cascades subregion. The chance of protection from catastrophic insect attacks in DCAs is high except for the occasional outbreaks of defoliators such as the western hemlock looper. Large hemlock looper outbreaks probably will not occur until large areas of older hemlock forests are restored. Other insects such as the Douglas-fir beetle may increase if large fires or large areas of blowdown occur.

Diseases

It will be difficult to completely protect DCAs from diseases. Many diseases, especially decay organisms and dwarf mistletoes, are desirable in terms of creating owl habitat. While removal of infected western hemlock trees is desirable for timber production, retention of some infected trees in managed stands will allow development of dwarf mistletoe trees in the future. Young trees may be protected from wounding to prevent entry of decay organisms, but eventually most trees will develop decay if they are left for more than 100 years. Older trees are much more likely to have substantial decay columns, especially white wood species like western hemlock, Sitka spruce, and true firs.

D. Forest Protection Guidelines

Fire

Intensive presuppression, detection, and initial attack, with high priority for suppression forces, are the most prudent course in the West Cascades subregion. This region is moist, and severe fire weather usually persists only for several days at a time. Fire suppression records in 1950-80 (Hardy 1983) show that the average size of Class E and larger fires (300+ acres) was relatively small in national forests primarily in this subregion: Olympic (897 acres), Mt. Baker-Snoqualmie (458 acres), Gifford Pinchot (1,458 acres), Mt. Hood (2,423 acres), and Siuslaw (none), in contrast to east side national forests, which averaged More than 2,500 acres for Class E+ fires. The Gifford Pinchot and Mt. Hood forests, with the largest averages in the subregion, have east side acreage and have the Columbia Gorge wind influence. Of course, larger fires have occurred within historical time in the subregion, and there is a chance of a series of large fires in this subregion similar to what apparently occurred in the past. Nevertheless, an aggressive fire control strategy appears to have a high chance of success here.

The primary fire severity level in this subregion is high (Huff 1984, Yamaguchi 1986, Gray 1990) so that stands burned are likely to be unsuitable for owls for decades to a century, assuming that snags and any residuals are not salvaged. In wilderness areas and national parks, a prescribed natural fire policy may be in place. If owl habitat is a primary management constraint, prescribed natural fire zones should exclude DCAs and should include an intervening buffer between the DCA and the prescribed natural fire zone.

If manipulation of stands is mandated (some portion clear-cut or partial cut), the use of fire to reduce hazard should be considered in a minority of cases, generally on the drier, more fire-prone sites. First, the risk of escaped fires exists (Dell 1977), although fire behavior usually is reduced once the fire enters adjacent uncut stands. Secondly, fuel hazards in untreated slash decline to levels similar to treated slash over a short time frame. Burning slash in these moist west side conditions may reduce fire hazard up to 15 years (Morris 1970) compared to untreated slash. Fine fuels fall to background levels for both precommercial thinning and blowdown within 2 to 4 years (Christensen and Pickford 1991). This is a temporal risk which is probably acceptable as long as contiguous slash is not present over thousands of acres.

From a fire protection standpoint, stand manipulation directed toward reduction of fire hazard in natural stands should be avoided. Instead, an aggressive fire control strategy should be implemented, with concentration on fire detec-

tion and initial attack. If manipulation is contemplated (for salvage, thinning), slash treatment should be considered on a minority of sites.

Wind

Most potential DCAs already have some clear-cut units within them. From a wind protection standpoint, adjacent areas are at risk. One option is to simply leave the existing units alone and accept the windthrow risk in the hope that additional damage will be limited to a couple of tree lengths into the stand. Another option is to enter adjacent stands along susceptible edges and "feather" the edges. The objective of feathering is to divert or break up the flow pattern of wind so it is not continually encountering a "wall" of trees. For a several-tree length reach, susceptible species or crown classes of trees can be thinned out. Residuals can be mechanically pruned; those on the leading edge can be pruned on alternate whorls to reduce wind pressure in the crown. All these techniques open the stands and reduce owl habitat for perhaps decades, but may stop an otherwise decades-long advancing wall of windthrow. Most stands affected by wind tend to rebuild wind resistance in this same manner. Such intensive management to build wind resistance has not generally been practiced in the Pacific Northwest, and its economics are unknown, but such management may be useful in areas bordering DCA units. Local expertise will be invaluable in designing wind-protected units.

Partial cutting may be employed in intervening areas between DCAs or potentially within a DCA (management directives not available as of the date of this report). Coastal areas (see Figure F.5), particularly the western Olympic Peninsula, are at greatest risk for accelerated windthrow. Recent experience is lacking in the Pacific Northwest, but guidelines from southeast Alaska (Harris 1989) may be relevant until more local experience is available: 1) stay out of areas with evidence of past blowdown; 2) avoid those stands exposed to storm winds (usually from southwest in our area); 3) avoid thinning more than 30 percent of the basal area of closed-canopy, even-aged stands; 4) thin from below and concentrate on trees with stilt roots, decay, or lean; 5) avoid damage to the residual stand; and 6) thin heavily at an early age to provide good rooting opportunity for residuals. Western redcedar seems to be relatively windfirm along the coastal margin (Harris 1989; Franklin, pers. comm.).

Windthrown areas have increased fuel hazards and higher potential fire behavior. The guidelines for slash treatment after partial cutting, summarized in the previous section, should be implemented in windthrown areas; treat slash in a minority of areas.

Insects

Under most conditions, active management for control of insect populations will not be necessary in DCAs. In the event of major windthrow where access is possible, some down timber should be removed to prevent large buildups of Douglas-fir and ambrosia beetle populations. Salvage could be done without negative impacts on fire hazard, but must be weighed against other habitat values of the windthrown trees.

Diseases

Foliage diseases are not likely to be epidemic. No sprays are recommended. It may be desirable to control root rots in some areas to prevent tree death and rapid stand succession. In some areas with good access, stump removal has been employed to maintain a relatively healthy stand, especially in areas with

high *Phellinus* incidence. In most DCAs, access for stump removal will not be good, and little active management of root rots will be feasible. Young stands should also be protected against the spread of black stain root disease which can be devastating. There is some evidence that thinning during summer may reduce infection. The usual timber management practice for controlling western hemlock dwarf mistletoe is to remove all infected trees. An alternative strategy, if timber management is to be practiced in DCAs might be to leave a few mistletoe-infected trees so that the habitat values produced by mistletoe will continue to be present into the future. There is concern that mistletoe infection will significantly reduce timber yields, and providing nesting platforms and nest boxes might be considered. Wounding of younger trees may be desirable to create entry columns for decay organisms at an earlier age than would occur naturally. This would be helpful for cavity-nesting birds.

IV. Forest Protection in the Klamath Subregion

A. The Natural History of Disturbance

Fire

The Douglas-fir forests of the Klamath subregion are among the driest forest types in which Douglas-fir is a dominant and where Douglas-fir old-growth is recognized (Old-Growth Definition Task Group 1986). The complex geology, land use history, steep environmental gradients, and variable fire history of this area have prevented generalizations about fire history and its ecological effects. Indians may have had significant ignition effects in these drier Douglas-fir forests (Lewis 1973, Boyd 1986). Miners, settlers, and trappers altered the patterns of burning in the 19th Century, and fire suppression has altered burn patterns in the 20th Century (Atzet and Wheeler 1982, Atzet et al. 1988). From the coastal forests of southwest Oregon to the crest of the Coast Range inland, the fire frequency decreases from perhaps 90 to 150 years to about 50 years. Frequencies averaging 20 years have been found in the eastern Siskiyou Mountains (Atzet et al. 1988), and Agee (1991b) has documented a similar fire return interval in the eastern Siskiyous between 1740 and 1860 before significant European settlement. In the Salmon River watershed in northern California, Wills (1991) found presettlement mean fire return intervals of 10 to 15 years for Douglas-fir/hardwood forests.

When fire return intervals are reduced to 50 years or less in these drier and warmer environments, a stand development sequence similar to that shown in Figure F.7 may occur (Agee 1991a). Beginning after a stand-replacement fire, the Douglas-fir regenerating on the site may survive several low to moderate severity fires that thin the Douglas-fir ("resisters"), remove the understory white or grand fir ("avoiders"), and topkill the associated hardwoods such as madrone, oaks, and tanoak ("endurers"). Several recurrences of such fires will create a stand with several age classes of Douglas-fir (some of which are large), and an age class of Douglas-fir and hardwoods representing regeneration after the last disturbance. Not every fire will result in Douglas-fir regeneration, suggesting many fires had little effect on the overstory canopy (Thornburgh 1982, Wills 1991). Understory-tolerant conifers of other species may be represented in post-fire regeneration. Large logs may be provided by residual Douglas-fir (or ponderosa or sugar pine where they are present) that have died from insects, diseases, or the last fire, or have blown over. In presettlement time, the

log and snag density was likely lower than at present because of frequent fires. At age 250+years, the structure of this stand may meet the old-growth criteria, having developed in a very different way than wet site Douglas-fir stands. Such stands usually will be intermixed with others that have experienced a stand-replacement event during one of the intermediate fires, so that the landscape is more patchy than in wetter Douglas-fir forests.

Along the coast, redwood forest exists along a fog belt and may extend up valleys with slopes dominated by Douglas-fir/hardwood forests. Veirs (1980) suggests fire return intervals in the northern redwood forests at 50 to 500 years, but other investigators working to the south suggest more frequent fire return intervals: 31 years at Humboldt Redwoods State Park (Stuart 1987), 20 to 29 years at Salt Point (Finney and Martin 1989), and 22 to 27 years at Muir Woods (Jacobs et al. 1985). The pattern of fairly frequent presettlement fire and moderate fire severity apparently existed almost to the coast in areas south of Eureka.

Wind

Wind appears to be an important disturbance factor primarily along the coast in the Klamath subregion. In coastal Humboldt County, average timber losses from windthrow exceeded the combined losses from fire, insects, and diseases (Oswald 1968), and Zinke (1988) noted wind-flagging along the coastal rivers in the redwood belt. Further inland, wind is not mentioned in a discussion of Douglas-fir/hardwood and mixed hardwood forests (Thornburgh 1982, Sawyer et al. 1988). Whittaker (1960), in his extensive monograph on these forests, does not include discussion of wind, although he recognizes the importance of fire. However, in ridgeline areas within the White Fir Zone of the Siskiyou Mountains, wind was implied to be an important disturbance factor (Agee 1991b).

Insects

Insects have historically caused disturbances in this subregion in association with fire. In natural forests insect populations were probably higher than those in the West Cascades subregion because of higher stress. However, there is a great deal of ecosystem variability across the landscape and the mixed species nature of the forests may have kept defoliator and bark beetle populations lower than anticipated. There is also a great deal of variability in the fire regime in this subregion.

Diseases

Root diseases were probably important agents of disturbance in this subregion. *Armillaria* probably killed stressed pines but wide tree spacing may have reduced its rate of spread through the soil. *Phellinus weirii* and *Heterobasidion annosum* incidences would have been related to development of susceptible Douglas-fir and true firs. *H. annosum*, although capable of causing root rot of pines, probably only attacked the most stressed individuals.

Dwarf mistletoe infections would have been lower in areas with frequent fires and slightly higher in areas with lower fire frequency. Natural rust populations, especially western gall rust, were lower and of course white pine blister rust was absent. Foliage diseases also would have been low. Butt rot and bole decay would have been important disturbance agents in older forests.

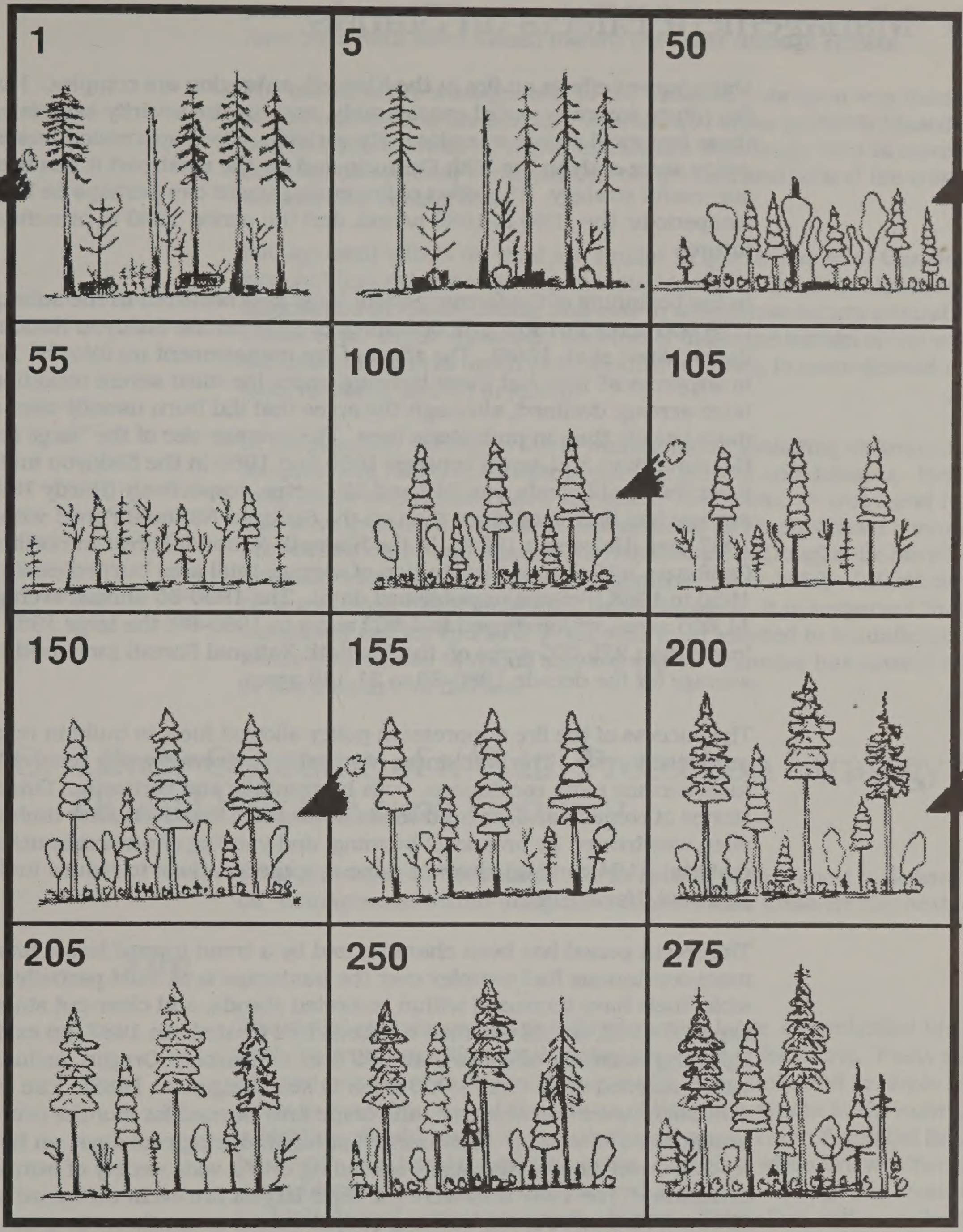


Figure F.7. *A stand development sequence for Douglas-fir/hardwood forest. After a stand replacement event, fires occur at return intervals of 50 years or less. Conifers are thinned/pruned while hardwoods are top-killed. Old-growth character develops, but through quite a different process than in the moist western hemlock/Douglas-fir type (see Figure 4).*

B. Management Effects on Stands

Management effects on fire in the Klamath subregion are complex. Historical fire return intervals varied considerably, and the fire severity associated with these historical events was also quite variable. Fire suppression has been a policy since early in the 20th Century, and for the most part it has been a successful strategy. The effect of fire management can perhaps be broken into two periods: the 1900 to 1980 period, and the period 1980 to present and the future.

In the beginning of the former period, large fires occurred in the subregion (179,000 acres in 1907; 152,000 acres in 1918 on the Siskiyou National Forest; Atzet et al. 1988). The effect of fire management up into the 1980s was to suppress all fires but those burning under the most severe conditions. Total burn acreage declined, although the acres that did burn usually were scorched more heavily than in prehistoric fires. The average size of the "large fire" (Class E+: more than 300 acres) between 1950 and 1980 in the Siskiyou and Rogue River National Forests was 747 and 327 acres, respectively (Hardy 1983). This average has ballooned since then on the Siskiyou National Forest with the 1987 fires (Helgerson 1988). In the Klamath National Forest in northern California, a U-shaped distribution of average total area burned exists from 1950 to 1988 (Perkins unpublished data). The 1950-60 annual average was 11,605 acres, which dipped to 4,862 acres in 1960-80; the large 1987 fires (more than 275,000 acres on the Klamath National Forest) increased the average for the decade 1980-88 to 31,140 acres.

The success of the fire suppression policy allowed fuels to build in remaining protected forests. The patchiness of variable fire severity was removed, and fuels became more continuous, both horizontally and vertically. Thick understories of conifers and/or hardwoods developed. Slash left after timber cutting often was treated by broadcast burning, and yarding of unmerchantable material (YUM yarding) also was done in some locations to reduce fuel hazard potential (Hardy 1983).

The recent period has been characterized by a trend toward larger fires. A more continuous fuel complex over the landscape is at least partially responsible, fuels have increased within protected stands, and clear-cut stands have exposed slash, not all of which has been fuel treated. In 1987, an extensive lightning storm set off more than 600 fires in southern Oregon, including 19 which reached more than 1,000 acres in size (Helgerson 1988). Fire suppression forces were overwhelmed, and some fires burned for months over rough, semiaccessible terrain. Fires burned at night, during cool days, on hot days, up and down slopes, essentially spreading over a wide variety of burning conditions. The 1987 fires were the third largest fire event on record in the Siskiyou National Forest, burning 190,000 acres in southern Oregon, more than half were on the Siskiyou National Forest. About 775,000 acres in northern California burned during the same time, mostly on national forest land (Atzet et al. 1988).

A mosaic of fire severity resulted. Less than half of the area of most of the southern Oregon fires burned with high intensity, with the remainder burning at moderate and low intensity (Gross et al. 1989). In northern California on the Hayfork District of the Shasta-Trinity National Forest, burned stands had about 5 percent of the area burned with crown fire consuming more than 50 percent of the crown; with another 25 percent of the area more than 50 percent scorched; about 32 percent was 10 to 50 percent scorched; while the remaining 38 percent was less than 10 percent crown scorched (Weatherspoon and Skinner unpublished manuscript). It is not possible to reconstruct what those

percentages would have been historically, but it is expected that they might have been even more biased toward the lower damage classes.

The effects of fire management in the Klamath subregion was then a 70-year period of declining fire acreage, with burned areas probably biased to the high scorch level, followed by recent experience with larger fires of more variable severity, due to their simultaneous occurrence and lack of fire control forces to immediately control them.

Management effects on wind are similar in type to the West Cascades subregion but less extensive due to dissected terrain. The forest landscape has been fragmented by clear-cutting, and loss to windthrow occurs around uncut edges (Stone et al. 1969). However, because of dissected terrain of the subregion and the inland nature of much of it, windthrow owing to management activities has been relatively limited in extent.

In the Klamath subregion forest management, including clear-cutting and fire suppression, has had a major impact on insects and diseases. Defoliator and bark beetle populations have increased. *Armillaria*, *P. weirii* and *H. annosum* also have increased. Specific diseases such as *Phytophthora lateralis* root rot of Port Orford cedar and black stain root disease of Douglas-fir have been dramatically increased by forest management (Baker 1988). Infections appear to be worse along roads for both of these diseases. It is suspected that road machinery carries spores of *P. lateralis* from infected to noninfected areas where they spread in runoff and soil water. Thinning has caused an increase in black stain root disease.

C. Likely Outcome of a Total Protection Strategy in DCAs Over the Next Century

Total protection in the context of this section of the report is defined as "hands-off" management within designated conservation areas for the next 100 years.

Fire

The recent experience in this subregion with large, uncontrolled fire events is likely to continue with a total protection strategy for DCAs. Fuels will only become more continuous with successful protection, and multiple fires are likely to recur because of the nature of lightning events in the subregion. Total protection should result in 1) a continued occurrence of isolated fires which burn with relative high severity, being controlled when fire weather shifts toward more moderate conditions, and 2) continued large fire "events" with multiple fires of many thousands of acres. These fires will overwhelm control forces and exhibit variable severity, with a skew over time toward the higher damage classes. A total fire protection strategy is likely to be unsuccessful, over the next 50 to 100 years, in providing protection against catastrophic disturbance in DCAs.

If timber harvest activity is undertaken in DCAs, fire management simulations (Hardy 1983) suggests that fuel treatment will be effective in reducing future burned area, although it may be cost-inefficient. Hardy's fuel treatment options were YUM yarding (8 inches x 10 feet or 6 inches x 6 feet), and his "base case" for wildfire size distributions (1950-80) did not include either the early 1907-18 fires or the 1987 fires, making fuel treatment compared to the "base case" hard to justify economically. A survey of partial-cut and uncut stands burned by the northern California fires of 1987 suggests that cutting was associated with increased fire severity levels, but fuel treatment within cut

units (underburning or lop/scatter) was effective in reducing damage compared to no treatment within cut units (Weatherspoon and Skinner unpublished manuscript).

Wind

Wind effects should not be exacerbated by total protection of DCAs. Continued limited blowdown should occur around the margins of currently clear-cut areas within DCAs. Unusual storms may accelerate this damage, but it is highly unlikely that a single storm or series of storms will cause massive blowdown within the DCAs of this subregion. This conclusion becomes more tempered toward the coastal edge of the subregion.

Total fire protection in this region usually will result in more insect and disease outbreaks because of increased stress. However, because of the patchy nature of the forest types and the fact that large landscape areas are not covered by a single species, insect outbreaks over extensive areas probably are not as likely as they are in the East Cascades subregion. Fire exclusion, however, will cause an increase in the Douglas-fir and true fir components of stands growing on dry, lower elevation sites. During drought periods the flatheaded fir borer and fir engraver beetle will cause extensive mortality in these stands; resulting fuels could cause increased fire problems. Root diseases, especially *Armillaria* root disease, and dwarf mistletoes are likely to increase.

D. Forest Protection Guidelines

Fire

There is likely to be a wide variety of opinion regarding the optimum fire management strategy for DCAs in the Klamath subregion over the next century. This variety is partly due to the fact that a total protection strategy, if successful, would produce the most acres of owl habitat. It is partly due to the uncertainty associated with global change; disturbance regimes are likely to be affected and may drive many of the vegetation changes projected under various global change scenarios. The range of opinions also is caused by a lack of consensus about how effective fire suppression alone may be, and what is gained by treating fuels in unmanipulated stands.

In our opinion, a total fire protection strategy has a fairly low probability of protecting owl habitat over the next century in most DCAs in the Klamath subregion. There is substantial reason to believe the trend toward large fires will continue, and fire severity will become skewed toward higher severity levels. Damage to understory and overstory will reduce or eliminate owl habitat in burned areas. Therefore, some type of fuel management program is recommended. Available data suggest that stands manipulated primarily for timber production will have increased fire severity levels. The fire management manipulations suggested below are specifically recommended for owl habitat objectives, not for timber production. There are probably ways the two could be integrated if timber management occurs within the DCA system.

Fuel and fire specialists in the vicinity of each DCA are the best qualified to develop the fuel management strategies. There is no reason to expect strategy to be the same in each DCA. The expected result of any strategy will be a temporary to permanent reduction in preferred owl habitat within the manipulated area, with a higher probability of control of potentially catastrophic wildfires over the larger area. Two types of fuel management strategies are

described, and an innovative fire management program will make use of both of them plus additional measures. The first is underburning, and the second is fuelbreaks; each addresses different objectives.

Underburning is an area treatment which eventually reduces total dead fuel loads and vertical fuel continuity. Wildfires entering such stands under most conditions have less severe overstory scorch and allow direct control of the fire. To be effective, underburning must be implemented over wide areas. For example, to the south at Yosemite National Park, some stands that had been underburned twice experienced crown fire behavior from wildfire that developed momentum as it crowned through adjacent brush and untreated stands (Wagtendonk pers. comm.). A first fire will consume much dead fuel, but also will create a lot (Thomas and Agee 1986). A second fire within the decade will consume the created fuel and maintain low fuel hazard for a longer period. Opening the understory reduces the protection offered owls and at least temporarily (1 to 2 decades?) provides less optimum habitat. Therefore, underburning should not be done over a wide area of any DCA within one decade.

The main objective of a fuelbreak is to compartmentalize units by creating a zone of reduced fuel between them, which allows safe access for fire suppression forces during wildfires and a reasonable control location (Green 1977). Fuelbreaks generally are placed along ridgelines where continuous fuels exist. Stands are manipulated to have discontinuous tree canopies, pruned boles on residual trees, and substantial understory removal (leaving a few clumps here and there). Some removed fuels can be utilized if good access is present; fine fuels are often pile-burned at the site. From a distance the fuelbreak need not be a visual eyesore and can be quite visually pleasing even at close range. A fuel manipulation in mixed evergreen forest below the developed area at Oregon Caves National Monument in the early 1980s is a good example of the visual advantages of understory thinning and fuel reduction. Indefinite maintenance of the fuelbreak in low fuel condition is essential. In the Klamath subregion, the occurrence of sprouting hardwoods with substantial regrowth potential (Tappeiner et al.1984) suggests maintenance intervals of a decade or less for fuelbreaks.

Underburn sites can be keyed into fuelbreaks to expand fuel-reduced areas. The underburning need not be done at historic return intervals. Monitoring of burned areas where owls exist should be done to determine what effects underburning has and how long they last.

If these fuel strategies are implemented over wide areas, conflicts with existing air quality guidelines are likely. The choice to be made is planned emissions or unplanned ones; absence of emissions is not a realistic option. An additional constraint on fuel management activities is that some DCAs may be partially within designated wilderness. Prescribed fire has been used in national park wilderness (Yosemite, van Wagtendonk 1985, Pinnacles National Monument, Agee and others 1981), but not to our knowledge in Forest Service wilderness (although policy now allows such use), which would be the primary management agency for wilderness in the Klamath subregion. Fuelbreaks have not been used in either type of wilderness, and increased use of prescribed fire might help to avoid placing fuelbreaks in wilderness. Consideration of fire management strategies in wilderness where DCAs exist should be done on a regional basis, but applied using local expertise. There will be some risk of escaped prescribed fires, some portions of which may be of high severity, even though they will be burning in early or late season. This risk cannot be eliminated, but it can be reduced with crew training, good ignition patterns, and patience. When compared to the alternative of attempted full suppression, the risk of escaped prescribed fires is reasonable to assume.

In the higher elevation White Fir and Red Fir Zones, where cooler climate and often lush herbaceous understories exist, fuelbreak and underburning activities probably are not needed specifically for owl habitat protection. A quick-response fire suppression strategy should be sufficient protection in these areas. Wilderness fire plans should be designed to mesh with the larger DCA fire management plans, and may consider either prescribed or prescribed natural fire as deemed appropriate by local fire management personnel.

Wind

Guidelines similar to those for the West Cascades subregion are applicable to the Klamath subregion. The zone of highest susceptibility is along the coast, but since this subregion is relatively mountainous right to the edge of the sea, the guidelines for the inland area of the West Cascades subregion are applicable. Along the coast, dominant coast redwood trees are relatively windfirm (Boe 1965) and should be favored in any stand manipulations such as thinnings or feathering operations.

Insects

Insect behavior will be largely controlled by fire frequency. There should be no need for spraying defoliators, but this option should not be ruled out if needed. Fuel treatment after harvest activity should keep the populations of Douglas-fir beetle and ambrosia beetles relatively low. Keeping stands in as low a stress condition as possible should reduce bark beetle attacks.

Fire

Total fire suppression increases root diseases, dwarf mistletoe infections, and decay fungi. However, it will be difficult to totally suppress fires and it is anticipated that diseases will not increase dramatically if fires occur.

V. Forest Protection in the East Cascades Subregion

A. The Natural History of Disturbance

Fire

Historical fire return intervals in the East Cascades subregion tend to be shortest in areas lower in elevation than what appears to be prime owl habitat. Moving from the sage steppe to ponderosa pine forests, neither of which is prime owl habitat, presettlement fire return intervals may be as low as 5 to 10 years (Bork 1985) in low severity fire regimes. As elevation increases, a more mixed conifer forest emerges, grading from the Douglas-fir series to the grand fir series of plant associations. Douglas-fir and ponderosa pine are dominant at the lower elevations and at higher elevations on ridges, while western larch, grand fir, and other conifers are found in addition on the more mesic or higher elevation sites (Sudworth 1908).

Stand replacement fires are not the most common fire severity that occurred in the Douglas-fir and grand fir series of plant associations (Keane et al. 1990). However, higher intensity fires are an important process for natural stand regeneration of western larch, lodgepole pine, and Douglas-fir, and have occurred in these areas at centuries-long intervals (Antos and Habeck 1981). Many intermediate fires of lower intensity and severity occur at a more frequent interval. In Montana, on a grand fir habitat type, the intermediate interval was about 17 years (Arno 1976). In the eastern Washington Cascades and Okanogan Highlands, the intermediate fire interval was estimated at 22 years (Finch 1984), with a range of 12 to 52 years. Fires of low to moderate severity are the most common types of severity in the moderate severity fire regime.

Unusual stand conditions created by a long fire-free interval or severe fire weather can result in a crown fire. Fuel conditions also can affect the probability of crown fire behavior. Pole-sized, heavily stocked stands have a high crown fire potential (Davis et al. 1980). If a young stand survives an initial light burn, perhaps due to its burning under average to moist weather conditions, subsequent underburns act as a negative feedback mechanism for crown fires by reducing fuels that might encourage crown fire spread. A long interval between underburns allows a tall understory to develop, which has a higher probability of crowning (Davis et al. 1980).

The successional dynamics of forests in the East Cascades subregion depend on the intensity of the fire as well as the species composition and structure of the vegetation at the time of the fire. Low intensity surface fires encourage western larch and ponderosa pine canopy dominance (Arno et al. 1985), as they are *fire resisters*. Their thick bark insulates the cambium against damage better than any of their associates, and in mature stands they are usually the taller trees, which helps them avoid crown scorch. The deciduous habit of larch may make crown scorch less important, especially for late season fires (Davis et al. 1980). Peterson and Ryan (1986) modeled the relative survival of a mixed conifer stand after a fire under moderate fuel moisture conditions with a scorch height of 30 feet. Mature western larch and ponderosa pine suffered no mortality in the simulation, while the basal area of other species, including Douglas-fir, declined 75 to 100 percent. After such fires, western larch radial

growth often increases (Reinhardt and Ryan 1988), while residual Douglas-fir may show no change in radial growth increment.

If a crown fire does occur, it kills all the trees in the stand. Herbs and shrubs may dominate the floristics of early succession, with some herbs (e.g., *Epilobium angustifolium*) peaking and declining within the same decade (Stickney 1986). Western larch has light-winged seeds, which can blow onto a burned site from adjacent stands or from lightly scorched cones in the fire-killed stand (Haig et al. 1941). Lodgepole pine, if present on the site, will establish from serotinous cones in the area. If the crown fires have been spaced more than 150 years apart, western larch is the most probable tree dominant at the time of disturbance, because lodgepole pine, the other early seral species with fast growth, is short-lived and may have been killed by mountain pine beetles (Haig et al. 1941). Where the crown fire interval is shorter than 150 years, lodgepole pine will at least share dominance in the post-fire tree cohort (Gabriel 1976, Antos 1977, Antos and Habeck 1981). However, if the stand is repeatedly underburned after lodgepole pine establishment, lodgepole pine will be eliminated because of its thin bark in favor of western larch, ponderosa pine, and Douglas-fir.

If two crown fires occur in quick succession, the site may revert to a brushfield (Antos and Habeck 1981), as neither western larch nor lodgepole pine survives such fires in the pole stage (Davis et al. 1980). Where a single crown fire occurs, stand establishment usually includes individuals of other species as well as lodgepole pine and larch. On dry sites, ponderosa pine may be included. On average sites, Douglas-fir and grand fir are normally present, and on moist sites western white pine may be a codominant. None of the associated species typically grows as fast as western larch and lodgepole pine (Haig et al. 1941, Cobb 1988). Individual species create different strata over time, although all may establish in the same time period. On a series of even-aged stands in eastern Washington that regenerated after crown fires, Cobb (1988; Figure F.8) found western larch to be a consistent dominant, with lodgepole pine sharing dominance on some sites. Douglas-fir and grand fir showed a variety of stratification patterns but always in intermediate or suppressed crown positions.

Low intensity fires in these stands increase the relative dominance of western larch, ponderosa pine, and/or Douglas-fir over their associates because of their crown position relative to grand fir, and thicker bark than lodgepole pine on dominant trees. Substantial understory development, perhaps after the breakup of lodgepole pine in the canopy, will encourage an *understory reinitiation* stage in stand development (Oliver 1981) which may be associated with increased crown fire potential and another set of multiple successional post-fire pathways.

A successional model of western larch/Douglas-fir forests, including fire dynamics was developed by Keane et al. (1990) for the Douglas-fir series in Montana. The model outputs generated by fire return intervals of 10, 20, and 50 years, and a no-fire situation are shown in Figure F.9. Ponderosa pine is most dominant in the more frequent fire return interval simulations. In the Douglas-fir series simulation, Douglas-fir is the most shade-tolerant species included and dominates the no-fire scenario. In the East Cascades subregion, the Douglas-fir series has little larch, and the fire scenarios would favor ponderosa pine with some Douglas-fir. The grand fir series is more common where larch is found; Douglas-fir in this series behaves more like larch while grand fir is the most shade-tolerant species. Substituting those species in the graphs gives a general idea of this alternative succession scenario: for example, in the no-fire scenario, larch, ponderosa pine, and Douglas-fir would decline and grand fir would increase.

Wind

There is no known published information concerning wind in the East Cascades subregion. This is likely because it is an intermittent and rarely extensive disturbance factor here. Our experience suggests that most natural stands and partial cuttings are relatively windfirm. Wind does not appear to be a factor of significant concern in designing a forest protection scheme for spotted owl DCAs in the East Cascades subregion.

Insects

Insects in this subregion historically have caused large disturbances. The frequent natural fire frequency on the eastern side of the subregion, however, probably did not allow populations to build frequently to the epidemic levels currently observed in this area. Insects probably acted as agents of stabilization in these ecosystems, similar to fire. Endemic populations of defoliators

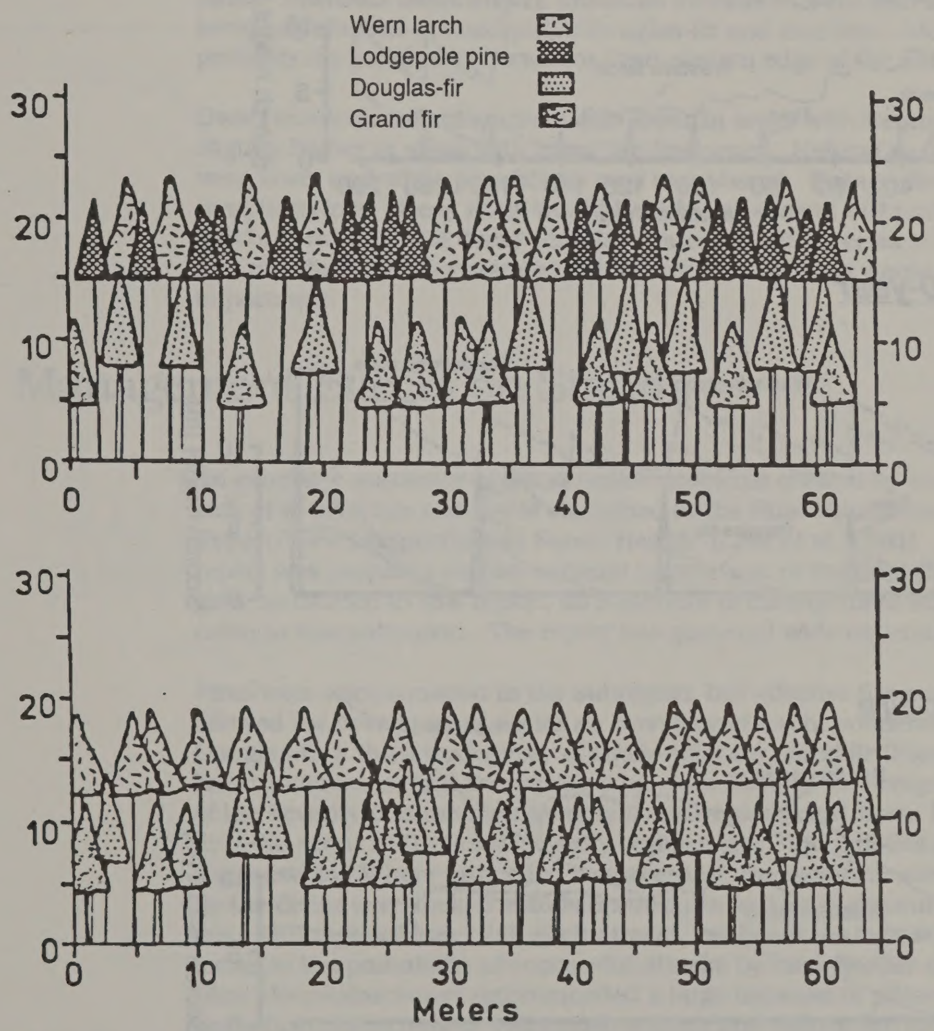


Figure F.8. In these mixed-conifer forests of the eastern Cascades, multiple canopy levels can be found in young stands (Cobb 1988). These stands are even-aged, both developing after a stand replacement disturbance. Larch and lodgepole pine dominate these young stands (100 years old) while Douglas-fir and grand fir are relegated to subcanopy positions.

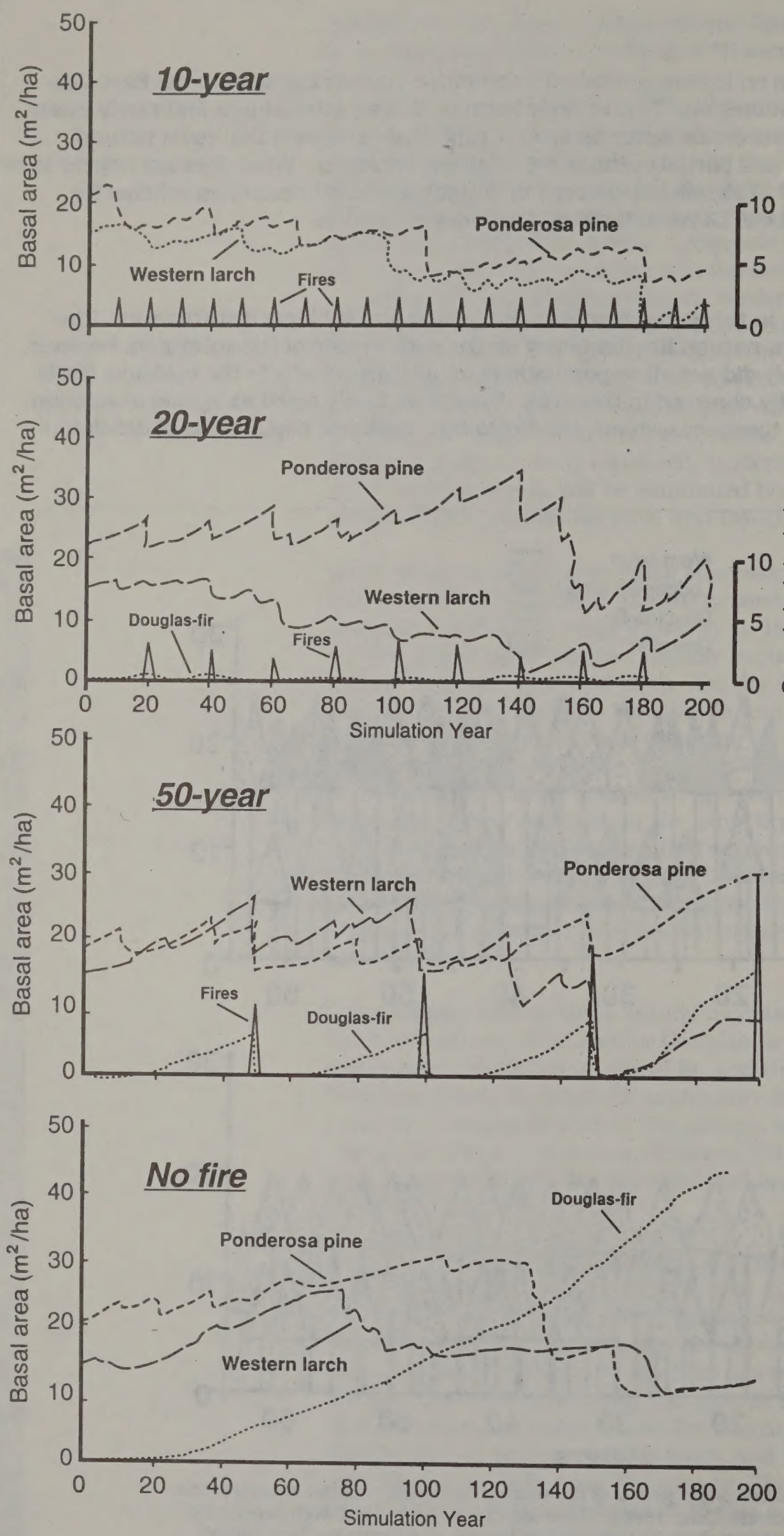


Figure F.9. *Simulations of relative basal area of species in mixed conifer forest under varying disturbance regimes (Keane and others 1990). As fire return intervals lengthen, ponderosa pine decreases in importance relative to Douglas-fir. Where grand fir is present, its response would be similar to that shown for Douglas-fir in these figures.*

(Douglas-fir tussock moth and spruce budworm) which tend to attack Douglas-fir and true firs could not easily build up in areas with frequent natural fire regimes because succession to the shade tolerant Douglas-fir and true firs did not proceed and stands were typically dominated by pine species. On the western edge of the subregion, where fires are less frequent, and Douglas-fir and true firs were more dominant, insect populations were historically higher.

Douglas-fir beetle, fir engraver beetle, and Cooley spruce gall aphid populations were generally low in areas with high fire freqency. Frequent fires also kept populations of mountain pine beetle, red turpentine beetle, and pine engraver beetles at low levels because tree density was low and trees were under relatively low stress. In areas with less frequent fires beetle populations would have been larger.

Diseases

Like insects, diseases in this area also acted as an agent of stabilization in natural forests. Root diseases such as *Armillaria* probably removed stressed pines. *Phellinus weirii* and *H. annosum* incidences were also lower because of lower populations of susceptible Douglas-fir and true firs. More root diseases probably occurred on the western than eastern edge of the subregion.

Dwarf mistletoe infections were also lower in areas with frequent fires and slightly higher in areas with lower fire frequency. Natural rust populations were lower and white pine blister rust was absent. Foliage diseases also would have been low. Decay fungi would have been present, but pines tend to have less butt rot and bole decay than later successional species such as Douglas-fir and true firs. In older stands butt rots and decay fungi would increase in importance.

B. Management Effects on Stands

An extensive summary of forest health problems created by management (or lack of it) over this century is contained in the Blue Mountains Forest Health Report "New Perspectives in Forest Health" (Gast et al. 1991). Although this report was prepared for two national forests east of the East Cascades subregion, as defined in this report, its summary of management impacts is applicable to this subregion. The report has garnered wide regional publicity.

Fires were once common in the subregion, but effective fire suppression has allowed the development under an overstory of larch, ponderosa pine, and Douglas-fir a thick understory of shade-tolerant grand fir (Figure F.10). Fire hazard increases, and fires which were once likely to be benign understory fires of low severity become high severity stand-replacement fires. High severity fires did occur in these low severity regimes (see Figure 3) but not at the scale they now do. Where protection is successful, the moisture stress experienced by the dense overstocked stands encourages spruce budworm attacks on the firs. Although seldom fatal, such attacks weaken trees over several years and increase the probability of successful attacks by bark beetles or root rots. The Blue Mountains report recommended a large increase in prescribed underburning to remove vulnerable species and reduce fire hazards (Gast et al. 1991).

With the exception of increased windthrow potential around edges of clear-cut, management has had little effect on wind in the East Cascades subregion.

In the East Cascades subregion forest management, especially high grading and fire suppression, has had a major impact on insects and diseases. Fire suppression and removal of desirable shade intolerant species, such as ponderosa pine, have favored shade tolerant Douglas-fir and true firs with very high stand densities. As a result insect and disease incidence in this subregion increased dramatically in the last 50 to 100 years.

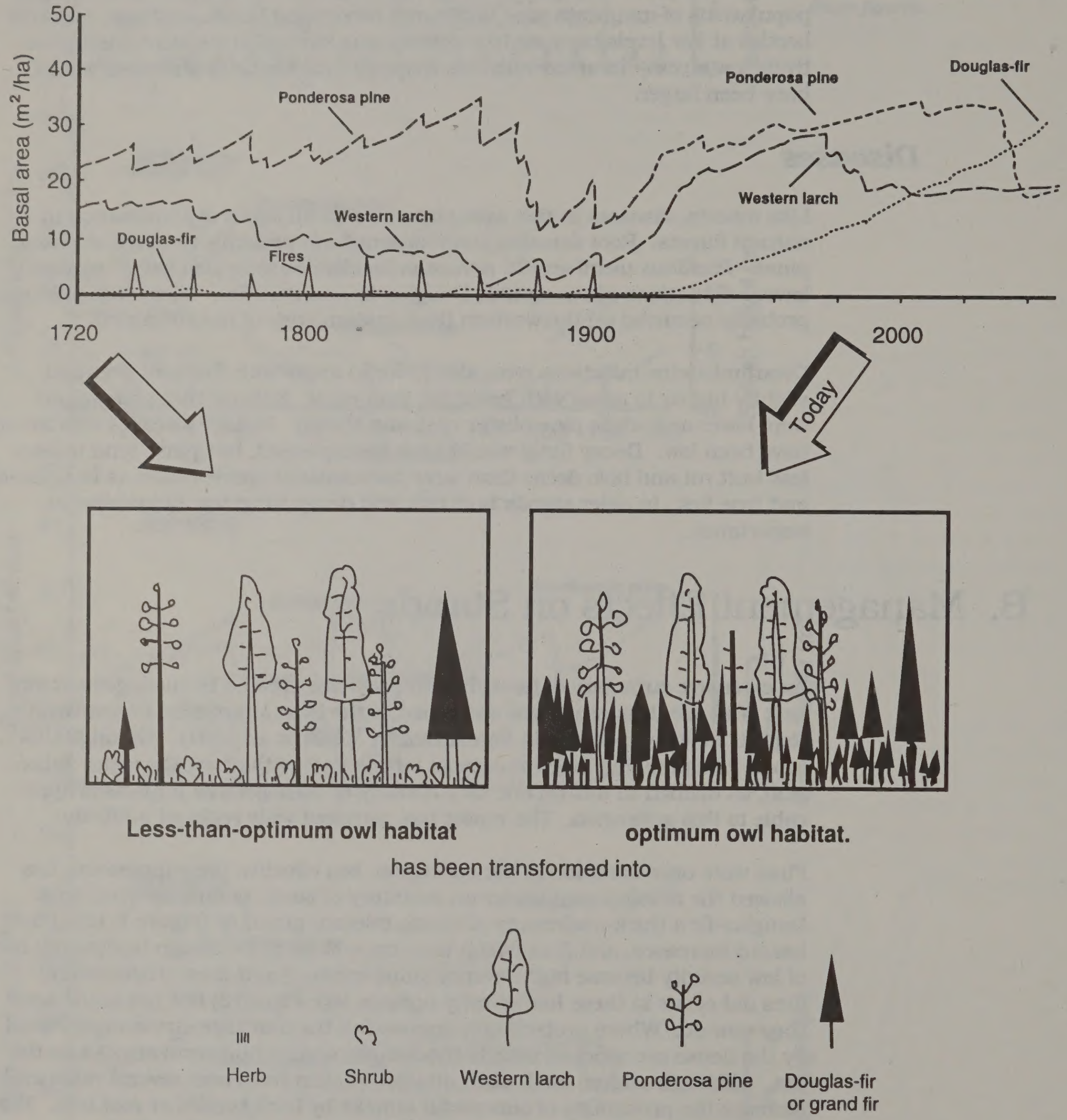


Figure F.10. *A simulation of ecological changes in East Cascades subregion forests due to successful fire exclusion. This graph was constructed by combining from Figure 9 the 20-year fire return interval simulation up to 1900 with the no-fire simulation after 1900. Shade-tolerant understory trees now choke the forest. Although such conditions may be conducive to owl habitat, there appears to be little historic precedent for current forest structure, and these habitats are likely to be significantly altered in the next several decades.*

Outbreaks of Douglas-fir tussock moth and spruce budworm occurred naturally but it is thought that management has increased outbreak severity. Such outbreaks can cover hundreds of square miles.

Swetnam and Lynch (1989) reconstructed the history of spruce budworm outbreaks in the southern Rocky Mountains from 1700 to 1983 using tree ring analysis and identified at least nine outbreaks. Severity and timing were highly variable. The average period of reduced growth was 12.9 years and ranged from 5 to 26 years. The average interval between initial years of successive outbreaks was 34.9 years and ranged from 14 to 58 years. There was a relatively long period of reduced budworm activity in the first decades of the 20th Century but since then outbreaks have been more severe. Current outbreaks may be more severe than outbreaks occurring under natural conditions. However, current outbreaks were not clearly less or more frequent than those during the previous 2 centuries. This change in severity was related to changes in age structure and species composition following harvesting and fire suppression in the late 19th and 20th Centuries.

Douglas-fir tussock moths also seem to have increased in severity. Although native to North America, tussock moths were not reported defoliating stands until 1908. Since that time infestations have occurred synchronously every 8 to 10 years over wide geographic areas (Brubaker 1978).

Spraying epidemic defoliator populations with chemicals and *Bacillus thuringiensis* has had little impact.

Douglas-fir and pine bark beetle populations all have increased resulting in widespread mortality across the landscape. Pine tip moth problems also have increased, especially in young plantations.

Fire suppression, high grading and changes in species succession also have changed the disease situation; root rot diseases are now extremely damaging, especially *Phellinus weirii* and *Armillaria ostoyae* (Baker 1988). *Armillaria* has become extremely damaging in the more stressful environment created by fire suppression. It kills all conifer species and all ages of trees in this subregion. It has increased dramatically as stumps have been created in managed forests with the subsequent increase in inoculum potential. Mixed conifer forests are often more severely damaged by root diseases after logging than before logging (Filip 1990, Filip and Goheen 1984). *Heterobasidion annosum* also has increased. It now causes considerable mortality in pine stands as well as root and butt rot in true firs. It may even occur in Douglas-fir. Some foliage diseases seem to have increased with management and larch needle blight is currently active over a wide area in eastern Washington.

Dwarf mistletoes also have increased in managed stands. Fire typically cleanses forest stands of dwarf mistletoe (Baker 1988). Douglas-fir, true firs, ponderosa pine, and lodgepole pine have become easily infected and now many of these trees have reached canopy dominance capable of infecting new trees in the understory. Interestingly, half of the owl nesting sites in the Wenatchee area of the East Cascades subregion are in dwarf mistletoe-infected Douglas-fir trees. Few of these trees would have existed in natural forests. Forsman et al. (1990) noted that owls utilize north-slope, closed-canopy forest more than the south-slope ponderosa pine forests. These mixed coniferous stands retain characteristics of mature and old-growth stands, such as snags and down trees, a moderate to strongly multilayered canopy and heavy infestation of Douglas-fir dwarf mistletoe. In the Wenatchee National Forest spotted owls were noted to nest in more or less even-aged Douglas-fir stands 90 to 130 years old with a high proportion of Douglas-fir (Buchanan pers. comm.). These stands were infected with dwarf mistletoe and more than half the owl nests were in mistletoe brooms.

The introduced disease, white pine blister rust, has been particularly devastating to western white pine and sugar pine. Native western gall rust has increased in plantations of lodgepole pine and also occurs in ponderosa pine.

C. Likely Outcome of a Total Protection Strategy Over the Next Century

Total protection in the context of this section of the report is defined as "hands-off" management within designated conservation areas for the next 100 years.

Fire

A total fire suppression strategy has created the multilayered yet unstable forest structure present on the landscape today. There is a very low probability that any DCA created in the East Cascades subregion will avoid catastrophic wildfire over a significant portion of its landscape over the next century. Most DCAs will exhibit landscape effects of fire similar to those in the Entiat River watershed. Fires of high severity and wide extent (with little overlap) have burned in 1970, 1974, 1976, and 1988 in areas once capable of supporting owls. In the 1970 fire area, many midslope and ridge areas exhibited a presettlement pattern of low intensity fires, with even-aged lodgepole pine stands in valley bottoms, suggesting longer interval, higher severity fires in the valleys. With the more continuous fuels provided by successful fire protection, the 1970 fires were more uniformly stand replacement in nature. One stump bared by salvage in a burned area of the 1988 fire showed a fire-free period of 99 years over which a dense, stagnated understory developed (a 60-year-old ponderosa pine was 2 inches in diameter). Before that, the tree survived underburns in 1870, 1860, 1850, 1830, and 1817, with earlier fire scars erased by the later burns.

Wind

If fires can be suppressed, root rots are likely to accelerate their spread. Trees significantly infected by root rots have an increased probability of windthrow. Such windthrow pockets begin as small circles and eventually widen as the root rots spread laterally to susceptible tree species. Resistant species will regenerate or be released in the openings, creating a younger, all-sized stand of primarily shade tolerant species. These are likely to be affected by other pathogens or insects and be heavily damaged by wildfires.

Insects

Fire exclusion, coupled with natural mortality factors, gradually reduce the pine and larch components of mixed conifer stands. Insect outbreaks associated with these seral species should show a gradual reduction in severity. However, the resulting multistoried stands of Douglas-fir and true fir create conditions for the buildup of defoliators. Douglas-fir tussock moth and western spruce budworm populations will increase, with frequent outbreaks. Episodes of tree defoliation and/or drought in east side stands will result in severe outbreaks of the Douglas-fir beetle and fir engraver beetle. Accumulations of heavy fuels within stands will make total fire protection very difficult. Large, fire-damaged Douglas-fir trees are susceptible to bark beetle attack.

Diseases

Total fire protection will continue to increase foliage diseases, such as larch needle blight, root rots, especially *Armillaria* root disease, heart rots (especially of true firs), and true fir and Douglas-fir dwarf mistletoes. As mentioned earlier, however, total fire protection in this subregion will be difficult to attain. Fires may reduce certain diseases, such as dwarf mistletoes, depending on fire intensity. They also cause wounding of some tree species, thus providing entry courts for fungi, especially bole decay organisms.

D. Forest Protection Guidelines

There are no forest protection options to maintain owl habitat at its current level in the East Cascades subregion. As noted, the current extensive habitat is likely a result of an historical anomaly: successful fire protection. The structure resulting from this anomaly is inherently unstable, subject to increased fire, wind, disease, and insect damage. Any stand manipulation which will significantly increase resistance to these disturbance factors apparently will result in decreased owl habitat, through reduction of thick understory conditions. However, there should be experiments to test the effect such manipulations will have on owl populations. Through the process of adaptive management (Walters 1986) future management direction will depend on the results of initial management efforts.

Many valley stands have longer fire return intervals than associated slopes. A prescribed burning program might be implemented on slopes while excluding toe slopes and valley bottoms. Such a program might protect nesting habitat in valley locations for a significant number of owls, while providing much more fire-resistant foraging areas on the slopes. Since north aspects appear to have more owl nesting sites (Buchanan pers. comm.) these aspects might be protected more often than south aspects. Wildfire control would have much more success if stands with thick understories were isolated and in riparian, north-aspect locations. Possible effects of fragmenting owl populations will have to be weighed against the benefits of hazard reduction. Effects of the burning on other wildlife and fish populations also might be more positive than negative if selected areas were excluded from the burning programs.

As in the Klamath subregion, tying in prescribed burning areas with fuelbreaks will increase the suppression capability when wildfires occur and aid in the implementation of a successful prescribed fire program with fewer escape fires.

Insects

In the absence of fire, spraying the forest with Sevin or *Bacillus thuringensis* has been recommended in some areas to reduce population levels of defoliating insects. This can also reduce tree mortality and lower the fire danger temporarily. However, such treatment is not likely to be very effective in DCAs or elsewhere and is not recommended as a DCA protection strategy. Stands may need to be thinned to keep them in a condition with less moisture stress to reduce the possibility of bark beetle attack and increased mortality. Thinning, however, may increase the incidence of root diseases such as *Armillaria* root rot.

Diseases

In the absence of fire, *Armillaria* root disease will continue to increase. Thinning to control bark beetles probably will increase the rate of spread. More

mortality will result and stands will become particularly vulnerable to fire because of heavy fuel loadings. Dwarf mistletoes will continue to increase in the absence of fire, particularly on Douglas-fir. With underburning, mistletoe-infected trees in the understory will be killed. Heart rots will also continue to increase in the absence of fire in older stands.

VI. Conclusions

Forest ecosystems are dynamic. They change with or without active management. In the case of unmanaged stands within the range of the northern spotted owl, such temporal change has been different within the three subregions defined in this report: the West Cascades, Klamath, and East Cascades subregions. Such change and the likelihood of successful protection of owl habitat by subregion is summarized in Table F.7, Klamath subregion. Clearly, active management is recommended for a majority of the land area occupied by the northern spotted owl, and within areas such as the Klamath subregion where the highest densities of owls exist.

A recommendation to implement a strategy that in fact reduces optimum owl habitat may seem a paradox. We believe that such implementation will in the long run better protect owl habitat than a more short-sighted attempt to continue total protection. Total protection would have been a viable 50-year strategy in 1910, but it is not viable in the 1990's. Active management of habitat in the Klamath and East Cascades subregions, through protection strategies designed to prevent large-scale catastrophic events, is the most rational management direction. In the West Cascades subregion, while we recognize that large-scale catastrophic disturbance is historically important, future occurrence is not predictable, and an aggressive fire control strategy is recommended. While these strategies are by no means perfected, they will help us learn through implementation, and hopefully ensure the long-term viability of the northern spotted owl.

Table F.7. A comparison by subregion of changes in forest structure since active forest protection began, the probability of continued successful protection, and needs for innovative management.

Category	Subregion		
	West Cascades	Klamath	East Cascades
Change in Unmanaged Stands with Protection	Low	High	Very high
Probability of Continued Successful Protection Over the Next Century	High	Very low	Very low
Need for Innovative Future Forest Protection	Low	High	High

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Appendix G

Managing Stands for Northern Spotted Owl Habitat

This report was prepared by Dr. John Tappeiner and the following scientists:

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Dr. Dale Thornburgh — Department of Forestry, Humboldt State University

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Table of Contents

I. Summary of Literature Review and Experience

This report discusses management of forest stands for northern spotted owl habitat. We present examples of silvicultural systems and treatments which resemble natural forest disturbances. These systems can be used to accelerate the development of stand structures used by owls and to grow habitat in stands where it is not likely to occur through natural stand development. We use stand structure (density, stocking by tree species and size class, snags, logs on the forest floor) of stands that contain owl nest sites as goals (or desired future conditions) for these silvicultural systems. We use data from actual stands to develop examples of silvicultural systems which will produce owl habitat.

A silvicultural system is a series of treatments to trees, shrubs, and other plants designed to produce a desired stand through time—in this case, a structure that provides habitat for northern spotted owls. The treatments and techniques employed necessarily will vary throughout the range of northern spotted owls. For example, in some forests in northern California and eastern Washington Cascades where there has been a history of harvesting individual trees or small groups of trees, there are mixed-species stands composed of trees of various sizes or ages. In these forests, silvicultural systems should maintain this diverse structure, while ensuring that there will be large trees in the future and protecting stands against fire, insects, and disease. In these forests, mimicking natural disturbance (i.e., fire) too closely may reduce owl habitat. In other forests of California, Oregon, and Washington, stands are composed of trees of relatively uniform sizes and ages. Here, silvicultural systems that attempt to mimic natural, small-scale disturbances and increase understory tree regeneration to develop multilayered stands seem appropriate. In many of these forests, windthrow and the regeneration of trees in dense understories of shrubs are probably of more concern than fire.

Not all these stands "need" to be treated to develop into suitable habitat. Some stands already provide habitat or will provide it in a short time without intervention. However, many other stands have been managed for wood production, not for owl habitat, and they will not readily produce multistoried stands without treatment. Thus, there are many stands in which treatment may hasten development of habitat, and many stands in which maintenance of habitat and wood production may occur simultaneously. The potential for a stand to produce owl habitat varies from stand to stand and depends on variables such as tree and shrub species composition; site productivity; and the age, size, number, and spatial distribution of trees. For example, stands with a high stocking of conifers will not quickly produce large trees with deep crowns or develop a multistoried structure. Stands with a dense understory of shrubs may not produce additional layers of trees because regeneration of trees cannot occur under the shrubs. Stands must be evaluated individually to determine their potential for producing habitat and which silviculture system to apply, if any. The possibilities for managing stands for owls are considerable. For example, we estimate that within the habitat conservation areas (HCAs) proposed by the Interagency Scientific Committee (ISC) there are more than 2 million acres in stands on federal lands in Oregon and Washington that are not suitable owl habitat.

Planning for silviculture systems to provide owl habitat must be done at the landscape and stand levels. Landscape variables to evaluate include location of owls; habitat for owl prey; types of stands not providing habitat including

area, structure, ages, location; need for fire protection and fuel breaks; disease and insect populations; access, and other uses. When thinning stands, for example, activities probably should be spread over time and space to avoid having large contiguous areas of temporarily open canopy, and to avoid nesting owls. Similarly, treatments such as prescribed burning to reduce fire hazard should be scheduled with regard to stand structure, owl use, fuel concentrations, fire control strategies, and other considerations.

A. Stand Structure and Owl Habitat

Owl habitat as used in this report is defined as the stand structures that owls use for nesting. This type of habitat is apparently the most critical for survival and recovery of owls. The structure has been quantified (see Appendix B) by studies in which tree diameter and heights as well as snags, logs, and other vegetation were inventoried in stands used for nesting. The structures of stands used for nesting are consistently multistoried with many small trees and fewer large trees per area (Figure G.1). They are typically mixed species with two or more age classes which have developed following one or more disturbances such as light fire, windthrow, and root diseases. Species in the overstory are generally redwood, ponderosa pine, sugar pine, western hemlock, and Douglas-fir, while the understory may include western hemlock, western red cedar, white fir, tanoak, bigleaf maple, and Douglas-fir on dry sites. There are often large dead trees and logs on the forest floor. The structures resemble those of old-growth stands (Spies and Franklin 1991).

B. Producing Stand Structure for Northern Spotted Owls

Actual examples of thinning show that reducing the density of overstory trees allows space for trees to produce large crowns and stems, and for trees and shrubs to be established in the understory (Figures G.2 and G.3). If stocking is not controlled, dense stands may develop (Figure G.4), and it would take many years for these stands to produce owl habitat.

The following key points emerge from the review of stand development history and literature (II and III) and from developing silviculture prescriptions (IV):

1. Disturbances of various sizes and intensities are a natural part of long-term forest stand development.
2. Many stands within the range of the owl are growing at high densities (many trees per area). Thinning these stands will increase growth rates, sizes of crowns, and diameters of remaining trees.
3. Mortality caused by suppression and crowding among trees is not likely to provide large snags or logs on the forest floor because only the smaller trees die. Thinning of stands will shift the size of a tree that dies from disease, insect, fire, and other causes, to large sizes.
4. To provide large snags and logs on the forest floor in young (30 to 80+ years) conifer stands, it often may be necessary to kill some of the larger trees in the stand. This is particularly true for stands regenerated after harvesting or reforestation following a fire.
5. Development of a multistoried stand from single-story conifer stands generally will require thinning, small openings in the canopy, or some other disturbance to reduce overstory density. If a dense layer of shrubs is present, disturbance or control of this layer likely will be required to establish conifers or hardwoods which can form the additional layers.
6. Young stands (10 to 80+ years) on productive sites develop quite rapidly.

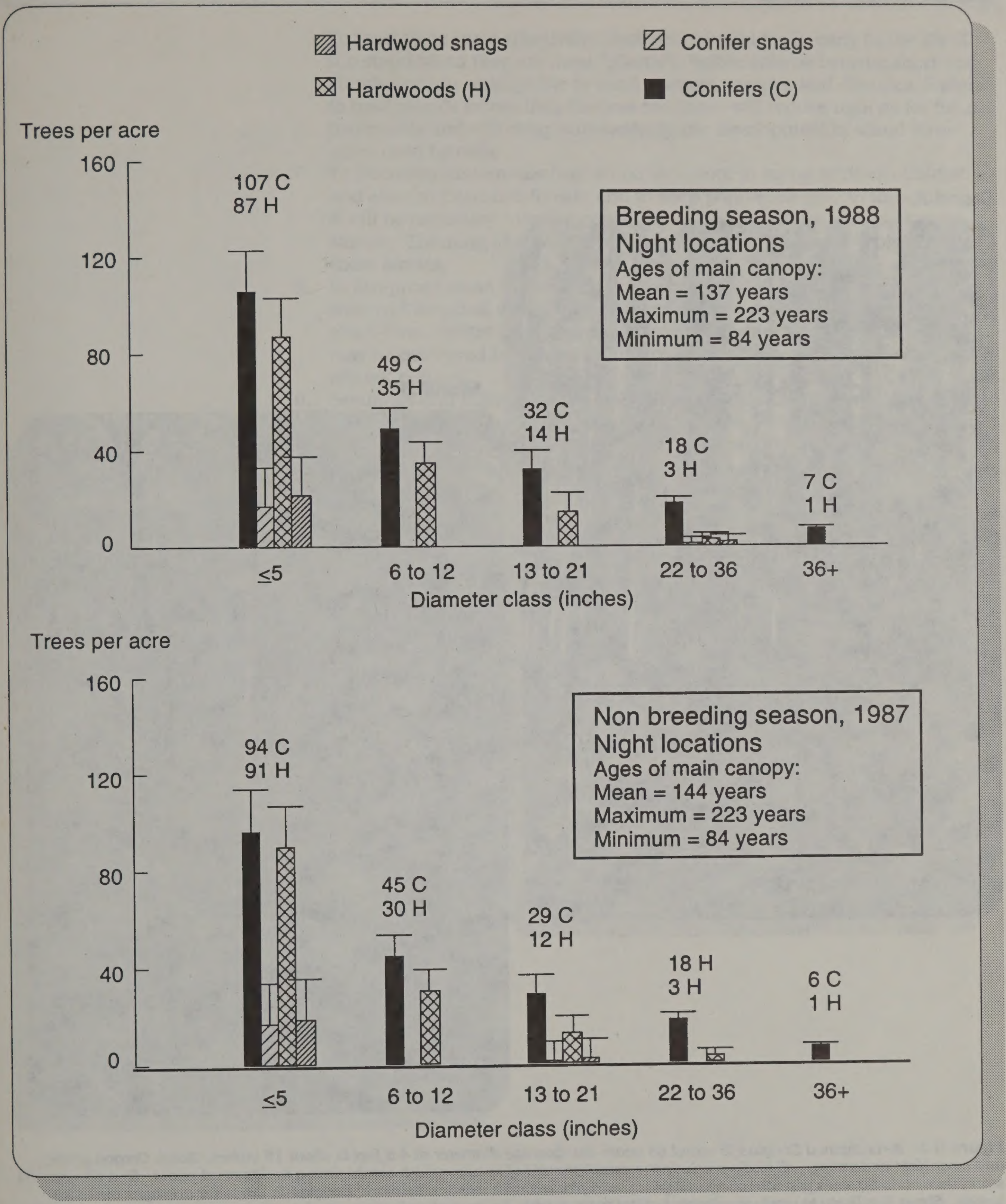


Figure G.1. *Examples of stand structure (numbers of trees and snags by diameter class) from stands used by spotted owls in northern California (Bingham pers. comm..). The same multilayer structure (many trees in small diameter classes and progressively fewer trees in larger classes) was similar for stands with nest sites throughout the range of the spotted owl. Vertical bars represent standard errors.*

Stand A

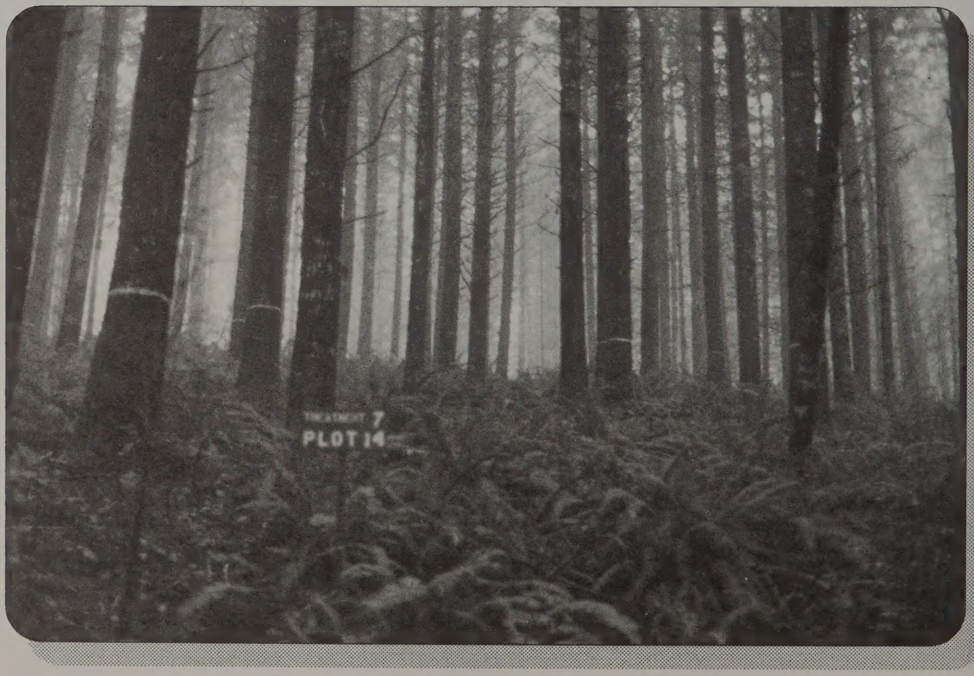
Stand B

Figure G.2. ***A***--*unthinned Douglas-fir stand 65 years old; average diameter at 4.5 feet is about 15 inches. Salal, Oregon grape, and swordfern understory will likely preclude the establishment of species which would form a multistoried stand.* ***B***--*a 65-year-old stand thinned to 50 trees per acre at age 45 years, and planted with western hemlock; Douglas-fir diameter averages about 29 inches. Stand B is likely to produce suitable habitat more quickly for spotted owls than stand A. Photographs taken near Falls City, Oregon.*

To treat them most effectively, treatment should begin early in the life of the stand when they are most "plastic", before crowns become short and stands become susceptible to wind damage, insects, and diseases. Failure to treat stands before they become too dense will reduce options for future treatments and will delay substantially the development of stand structures used by owls.

7. To maintain uneven-size/age stand structure in many northern California and eastern Cascades forests and to keep ponderosa pine in these forests, it will be necessary to make openings and to thin dense stands or parts of stands. Thinning also will help relieve disease and insect problems in these forests.
8. In fire-prone areas in northern California, southern Oregon, and the eastern Cascades, where natural fire has been excluded, there may be short-term habitat improvement. However, in the long term these stands may be destroyed by fire if fuel loading and the potential for severe wildfire are not reduced.
9. Seedlings and saplings of shade-tolerant conifers and hardwoods needed to form multistory stands will be present in some stands as advanced regeneration. In other stands, it will be necessary to control dense shrub/hardwood understories to attain regeneration by planting or seeding.

Figure G.3. *Effects of thinning Douglas-fir. Stands are about 40 years old. Photograph taken near Hoskins, Oregon (Curtis and Marshall 1986).*
G.3.A. *(treatment 9) = no thinning. No understory; average tree diameter at 4.5 feet is about 12 inches.*



G.3.B. *(treatment 7) = lightly thinned. Some understory development; average diameter is about 18 inches.*

***G.3.C.** (treatment 1) = heavy thinning. Considerable understory; average diameter about 20 inches. See Figure G.5 and G.6.*

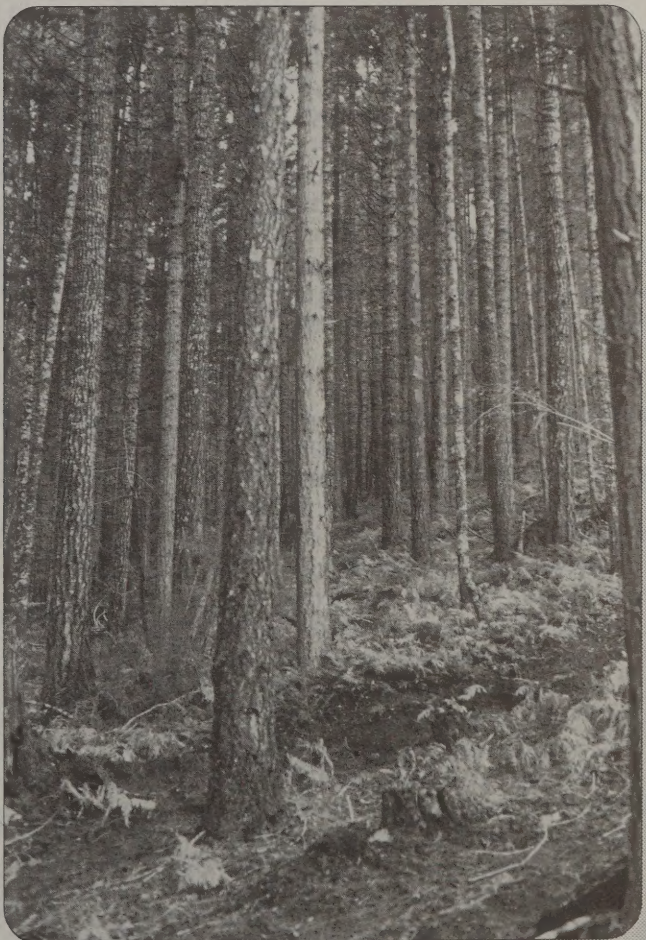


***Figure G.4.** An unthinned, dense Douglas-fir stand about 70 years old, with no understory. Careful thinning and making small openings, followed by establishing shade-tolerant tree species, would aid the development of a multistoried stand and owl habitat. Thinnings at earlier ages would have resulted in trees with larger diameter stems, longer crowns, development of an understory, as well as commercial wood production.*

II. Review of Natural Vegetation and Stand Development — History of Forest Management

A. Coastal Forests and Western Cascades of Oregon and Washington

Forests on federal lands in the western Cascades and Coast Range mountains of Oregon generally are classified in the western hemlock and silver fir zones by Franklin and Dyrness (1973). There is generally plentiful moisture throughout these zones, and plant associations range from oxalis and sword fern on moist sites to Douglas-fir, ocean spray, vine maple, and salal on drier sites. Older stands in these forests often have a well-developed understory of shrubs and hardwoods such as vine maple, yew, bigleaf maple, salal, salmonberry, rhododendron, hazel, ocean spray, and huckleberry. Conifers in the understory are primarily western hemlock and western red cedar on moist sites. Grand fir and Douglas-fir may occur on dry sites, and silver and noble fir at upper elevations.

1. Natural Forest Development

Natural disturbances in these forests occur over a range of sites, frequencies, intensities, and patterns. Under natural conditions, stand replacement fires occurred at intervals of about 95 years to more than 500 years (Appendix F) with the longer intervals on moist sites. These fires often burned many thousands of acres. The mortality of the overstory within these extensive burns varied considerably (Spies and Franklin 1991, Morrison and Swanson 1990). Groups of trees and scattered individual trees often survived more than one fire. Thus, the Douglas-fir overstory in old-growth forests is often multi-aged (Franklin and Hemstrom 1981). Even with fire suppression, large fires can occur, for example, the Tillamook burn in the 1930s and the Oxbow fire in the 1960s.

Wind effects are most severe on ridge tops and near the coast and Columbia Gorge, although severe storms like the Columbus Day Storm of 1961 caused major disturbances on a wide range of sites (Ruth and Harris 1979). Wind effects are often small-scale, blowing down small groups (less than one acre) and individual trees and breaking tops; although entire stands (more than 20 acres) may be blown down. Insect populations (bark beetles) often increase after fire or blowdown.

Root and stem diseases are widespread, but they generally occur on a smaller scale than wind and fire. They slowly kill groups of trees. Over extensive areas, root disease may affect more than 10 percent of the entire area. Other agents of disturbance include ice storms, which mostly break the tops of stands of young trees, and mass movement such as landslides, which are important locally.

Individual trees also die because of competition among trees (Drew and Flewelling 1979). Self-thinning is a natural part of stand development and occurs much more quickly on more productive sites than on poor sites. Rate of self-thinning is dependent on species composition and stand density.

These factors act together to affect the rate and course of stand development (Spies et al. 1991). For example, natural succession after fire likely would result in a variety of young stands irregularly stocked with conifers, shrubs, and hardwoods, some large green trees not killed by the fire, and often large accumulations of snags and down logs from the previous stand (Spies et al. 1988). As stand development continued, conifers would dominate parts of stands and if they are dense enough, shrubs and hardwoods would be excluded (Oliver 1981). In other parts of the stand, conifers would grow in the open and develop large crowns and branches, and patches of shrubs and hardwoods would remain. After about 80 years, wind, pathogens, and self-thinning would kill individual overstory conifers and groups of conifers producing openings, snags, and down logs. Patches of shade-tolerant conifers, hardwoods, and shrubs would grow in the openings (Alaback and Tappeiner 1991). Where shrub layers were dense, tree regeneration would be excluded or time for its establishment greatly extended. This process of disturbances at irregular intervals would continue producing waves of tree and shrub regeneration, snags, and down logs and providing a diverse structure (Spies and Franklin 1991, Spies et al. 1988, Spies et al. 1990).

Natural disturbances to forest stands vary in intensity, distribution, frequency, and size. Viewed in the context of the home range of an owl (about 3,000 acres, for example) these disturbances may be extremely small (a 0.05-acre opening, less than 0.0002 percent of a home range) or they could include the entire home ranges of one to many spotted owls.

2. Forest Management and Stand Development

While timber harvest on private lands began in the late 1800s, major timber harvest programs by the Forest Service and BLM started about 1945 to 1950. Due to concerns for road access, logging methods, watershed impacts, and providing edge for elk and deer, "patch cutting" (usually more than 20 acres) was used; that is, stands scattered throughout a watershed were clear-cut and planted. Since harvesting on federal lands began about 40 years ago, today in most watersheds young stands are usually 0 to 40 years of age, and there are natural stands of large old trees. Thus, today there is a strongly bimodal age distribution between managed and unmanaged stands. In addition, there are some natural stands of intermediate ages resulting from fire, wind, and earlier harvesting. Harvest by thinning in some areas also has occurred in the last 20 to 30 years.

Treatments to establish plantations following clear-cutting or fire have tended to alter secondary succession to ensure well-stocked conifer stands. The course of forest succession following fire or harvesting of mature or old forests varies depending upon severity of disturbance, composition of preharvest vegetation, site conditions, availability of conifer seeds, and animal population levels. In most situations, if Douglas-fir seed is not available in sufficient quantities immediately after harvest, tree regeneration is slow and irregular and generally unacceptable in terms of meeting wood production objectives. Because of this long, natural regeneration period, most sites are planted as soon after harvesting as possible. To reduce growth of broad-leaved trees, shrubs, and herbs, some type of site preparation (fire, mechanical, chemical) is done following harvesting and before planting. Planting often is followed by some treatment that reduces density and vigor of nonconiferous vegetation. The purpose of these practices is to obtain a uniform conifer stand and quickly achieve conifer crown closure thereby shortening the period of dominance by nonconifers. Stocking control is important for obtaining correct stand structure. Precommercial thinning is done often in 10- to 20-year-old stands to ensure uniform conifer spacing and control density of conifers and hardwoods. This is especially necessary on coastal sites where natural regeneration of

western hemlock, and sometimes other conifers, occurs among planted seedlings and dramatically increases stocking (700 + trees per acre). Forest stands, especially plantations established for timber production, often will proceed through a stem exclusion stage (Oliver 1981) in which shrubs and hardwoods die or become substantially suppressed by a dense conifer overstory. Most of the understory plants likely will die if hemlock is the main overstory tree (Alaback 1982), because its foliage is denser (high leaf area index) compared to Douglas-fir (Waring et al. 1978). Thus, plantations, because of their lack of large trees and snags from the previous stand, and regular, close spacing, may develop stands that are quite different from young natural stands (Spies et al. 1988).

On coastal sites, red alder stands frequently have become established. These stands often have salmonberry or salmonberry-sword fern understories which prevent conifer establishment. The shade from the salmonberry and browsing from mountain beaver often found in salmonberry-dominated communities prevent conifer regeneration. Alder stands with salmonberry in the understory, unless treated to establish conifers, are unlikely to produce conifer stands capable of developing owl habitat because the salmonberry will form a dense, persistent shrub layer as the alder dies and will retard invasion of conifers (Tappeiner et al. 1991).

B. Northern California and Southwestern Oregon

1. Natural Forest Development

The vegetation comprising owl habitat in southwestern Oregon and northern California is quite diverse. It includes redwood forests (Zinke 1977), mixed evergreen forests (both hardwood and conifers) (Sawyer and Thornburgh 1977a) and mixed conifer forests (Sawyer and Thornburgh 1977b). Atzet et al. (1992) have classified the vegetation of southwestern Oregon into 16 series and each series usually is subdivided into several plant associations (more than 200 total). The most common series are white fir, western hemlock, Douglas-fir, tanoak, and mountain hemlock. These vegetation series and their included associations vary by elevation and aspect and occur on a variety of soil types, including soils of volcanic and metasedimentary material. There is generally less precipitation in this area, except near the coast, than there is in the western Cascades and northern coastal forests. Climate is Mediterranean, with strong coastal and continental influences. In northern California, the most common vegetation series include redwood, Douglas-fir, tanoak, and white fir.

Fire occurs in forests of all vegetation series. Natural fire return intervals vary from 20 to 200 years (Atzet and Wheeler 1982) (Appendix F). More frequent and less intense fires generally occur on drier sites at lower elevation, with less frequent stand-replacement fires at higher elevations or near the coast. See Walstad (1992) for a discussion of recent fire history. Accidental ignition and purposeful use of fire by Indians and European settlers also has had a major impact on the forests.

Factors which affect natural succession and management of landscapes and individual stands in this region include fire, wind, insects, pathogens, and browsing by animals. Chance of ignition is high on interior sites due to lightning and human causes. Fires are likely to be intense because of the summer drought, steep terrain, and accumulation of fuels due to fire suppression and logging slash. The likelihood of fire and its effects vary by forest type. Fire is not expected to be a severe problem in most of the redwood forests or coastal

Douglas-fir forests. Fire (or some other disturbance) is, however, important to help conifers maintain dominance over hardwoods in mixed evergreen forests (Thornburgh 1981, Hoover 1988).

Pathogens (such as black stain and annosus root rot) and insects (such as western and mountain pine beetle, fir engraver beetle) are most likely to cause conifer mortality on dry interior sites. Insects are particularly likely to affect dense stands where poor tree vigor may predispose stands to attack, especially in periods of drought. Root disease also may make stands susceptible to insects. Ice storms and wet snow can uproot large, broad-leaved evergreen trees in the mixed evergreen forests.

Wind can be a major factor on coastal sites, especially when large individual trees are left in shelterwoods. Hemlock, Douglas-fir, redwood, sugar pine, and ponderosa pine are susceptible to windthrow, which is locally important on interior sites and most likely to occur on ridge tops, saddles, and in conifer stands on shallow soils or infected with root diseases. Pocket gophers and browsing deer and livestock, which are important factors in the establishment and growth of planted and natural conifers, may have major effects on reforestation in some areas.

Four to five decades of fire suppression and timber harvesting have influenced today's forests. Fire suppression likely has favored the development of the understory of tanoak, a shade-tolerant hardwood, which is a climax species in the tanoak association and an important component of the Douglas-fir, white fir, and western hemlock associations. Fire exclusion also has favored the development of hemlock and white fir understories on some mesic sites, Douglas-fir understory on dry sites, and a tanoak understory beneath redwood. To the extent that a well-developed understory is important for owl habitat, fire exclusion probably has improved owl habitat. Recent large, variable-intensity fires have increased the structural and species diversity of mixed evergreen and mixed conifer forests in northwestern California (Thornburgh 1991).

2. Forest Management and Stand Development

Logging in this area began about 1830. Large-scale commercial harvesting began about 1915, but was confined to gentle terrain (Walstad 1992). Cutting rapidly increased after 1945. Effects of logging varied tremendously. In some cases, only certain species were cut and large trees of nonmerchantable species were left (partial cutting). Also, shelterwood methods and, more recently, clearcutting were employed. Partial cutting and shelterwood regeneration method probably have favored the establishment and growth of Pacific madrone and white fir and the growth of established tanoak. In general, the types of stands present today include: a) old-growth stands undisturbed, except for fire suppression; b) stands composed of varying numbers and species of conifers and hardwoods released by logging, residual old-growth trees, and natural regeneration of conifers, hardwoods, and shrubs following logging; and c) relatively uniform young stands that contain shrubs, hardwoods, and other conifers that have been established by natural seeding and planting.

C. East Cascades of Oregon and Washington

The forests in the east Cascades, inhabited by northern spotted owls, generally are composed of mixed conifer stands in the Douglas-fir and grand fir plant associations. Under natural fire regimes these forests had intense fire, at possibly centuries-long intervals, and light underburns at about 10- to 20 -

year intervals (Appendix F). With the reduction of fire during the last 6 to 10 decades, forests have become quite dense and multistoried, primarily from the invasion of more shade-tolerant grand fir, Douglas-fir, and Englemann sprüce. Lack of fire likely has resulted in better owl habitat.

Insects and diseases are of major concern in many of these forests. Defoliators and bark beetles are common, as are root diseases (*Armillaria, Phellinus* and *H. annosum*). Insects and diseases probably have increased as shade-tolerant conifers invaded after fire suppression (Appendix F). These forests frequently have been managed by individual tree selection with the goal of salvaging larger dead or diseased trees. This practice, along with fire exclusion, has contributed to today's mixed species, multistoried stands. Fire hazard is high due to the dry climate, fuels from dead trees, and the multistory structure (Appendix F).

III. Stand Development and Management

The studies and models discussed here were designed to understand and predict the effects of thinning and regulating stand density on forest stand growth, development, and yield. They were not designed specifically to determine how to provide owl habitat. For example, they do not provide information on snag production from mortality of larger trees or the development of large limbs or cavities which may be used as nest sites. Nevertheless, these studies are valuable background for developing silvicultural systems to provide habitat. They show that tree size and stand structure can be regulated by careful management of stand density. There are growth models, applicable to the forests used by owls, which can be used to predict trends in stand development, tree size, crown cover, mortality, and other factors. Background information and techniques are available that can be applied to stands of various ages, structures, species composition, and sites to grow stands for owl habitat. There is a large body of literature on stand growth and development dating to Europe in the 19th Century (Assmann 1970) and it includes many studies in North America. However, we will discuss only the information developed from studies in forests within the range of the northern spotted owl.

A. Stand Manipulation and Thinning

Numerous studies have shown that regulation of stand density affects individual tree and stand characteristics such as crown length and width, branch and stem size, leaf area index, vigor, and wind stability. Effects are apparent in young and old stands. Reukema (1975) summarized information from replicated spacing studies, established 50 years earlier at Wind River Experimental Forest. On these dry sites, high stocking reduced height and diameter growth rates and resulted in stands of poor vigor. Eversole (1955) recognized these trends when the stands were 25 years old, and there was no reversal of trends in height and diameter growth rates during the intervening 25 years.

The most thorough study on the effects of management on young Douglas-fir is the regionwide "levels of growing stock study" (Marshall 1990, Curtis and Marshall 1986, Williamson and Curtis 1984, Tappeiner et al. 1982). The study is being conducted on five study sites with each of nine treatments replicated three times at each site. Treatments range from no thinning to intensive thinning, with only about 50 trees per acre remaining at age 40 years. This study shows that in stands on a wide range of site productivity, frequent

thinning has altered substantially stand structure and tree growth. For example, after 25 years at the Hoskins, Oregon, study site, diameter distributions, crown length, wood volume, and basal area growth were altered by thinning (Marshall 1990). The average diameter of the stands, especially the numbers of trees in the larger size classes, increased following thinning (Figure G.5). For example, after heavy thinning, diameters ranged from 16 to 24 inches; after light thinning they ranged from about 4 to 20 inches. The crown size of individual trees and understory development increased as thinning intensity increased (Figure G.6). Understory biomass increased from about 9 pounds per acre in unthinned plots to more than 6,300 pounds per acre with heavy thinning. The trends and actual values for diameter (Figure G.7) and other parameters at the other sites were quite similar to those at the Hoskins, Oregon, study site (Curtis and Marshall 1986).

Thinning regimes can be flexible and Douglas-fir stands can respond equally well to different intensities and timing of thinnings (Reukema 1972). Stands 38 years old were thinned: a) lightly (12 percent volume removed) at 3-year

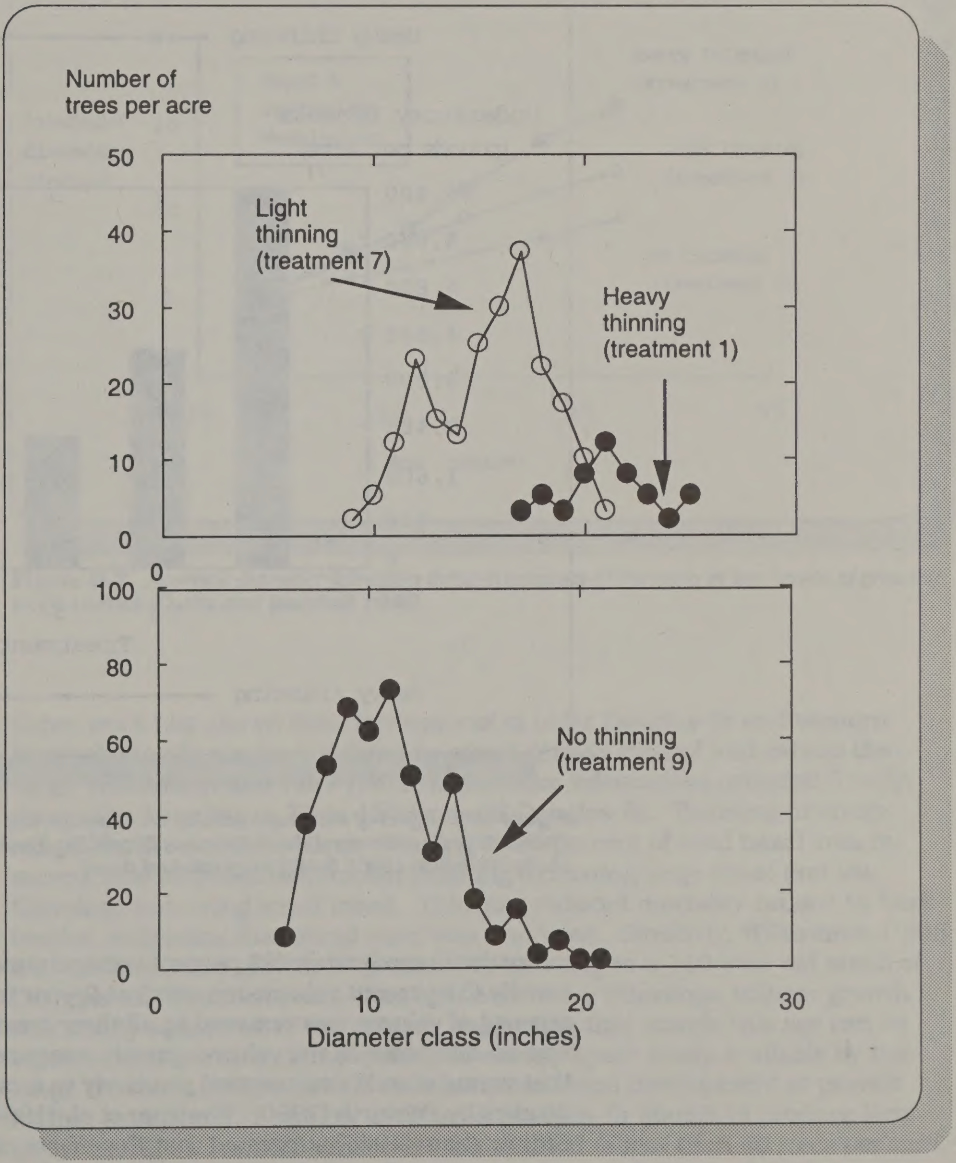


Figure G.5. Number of trees per acre by diameter class at age 45 years; 20 years after thinning. Hoskins, Oregon, level of growing stock study (Marshall 1990).

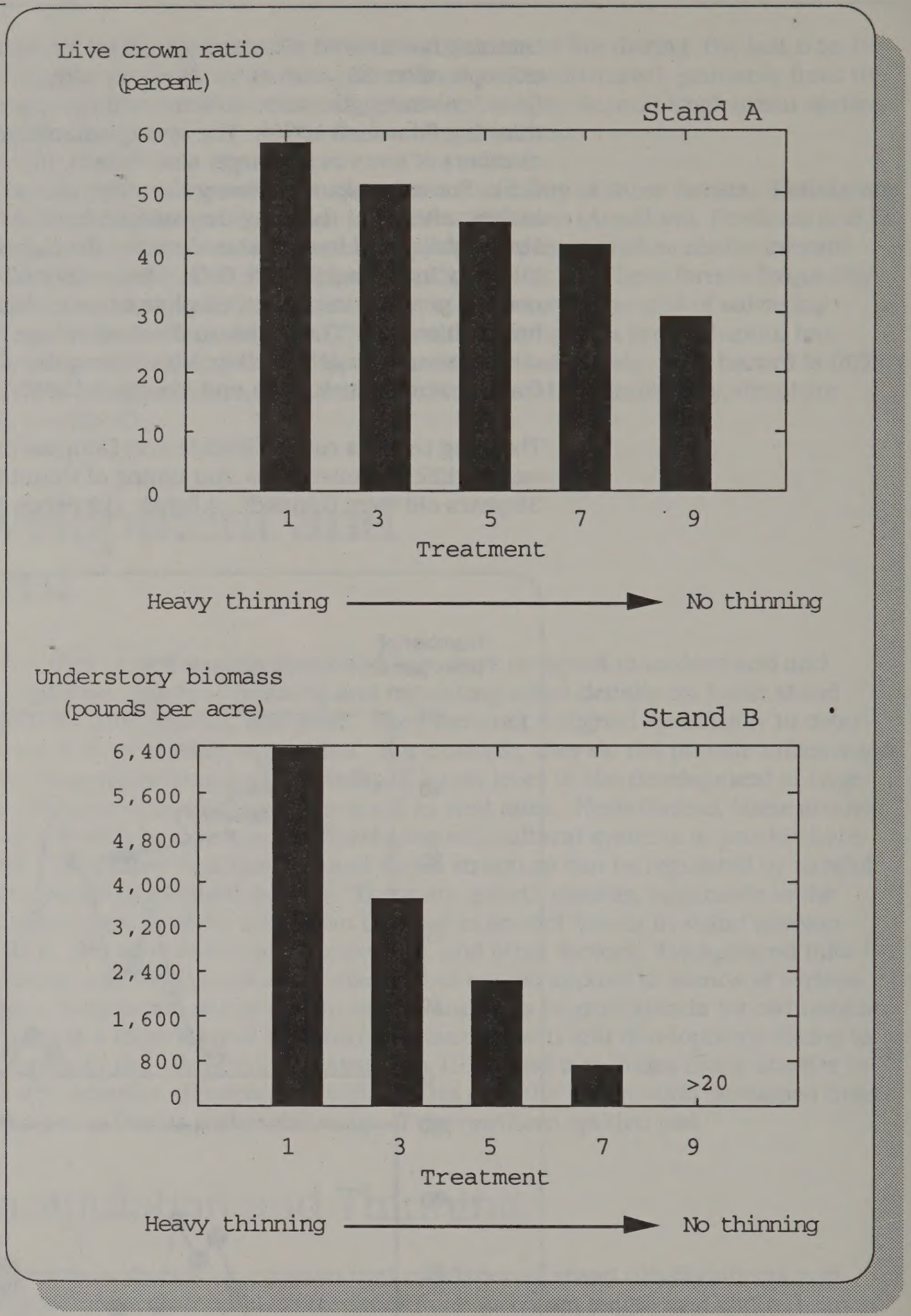


Figure G.6. *Effect of thinning intensity on: average live crown ratios of Douglas-fir trees (Stand A) and understory shrub biomass (Stand B). Hoskins, Oregon, levels of growing stock study (Marshall 1990), Sutliff (unpublished data).*

intervals, b) moderately (22 percent volume removed) at 6-year cycles, and c) heavily (31 percent volume removed) at 9-year intervals. About the same amount of volume was removed in all three treatments. After 18 years, there was no difference in net volume growth compared to the controls, indicating that young stands can respond positively to a range of thinning regimes. Studies by Dilworth (1980), Nystrom et al. (1984), and Greene and Emmingham (1986) suggested that the effects of density on the development of young western hemlock and western red cedar stands are similar to effects on Douglas-fir (see King 1986).

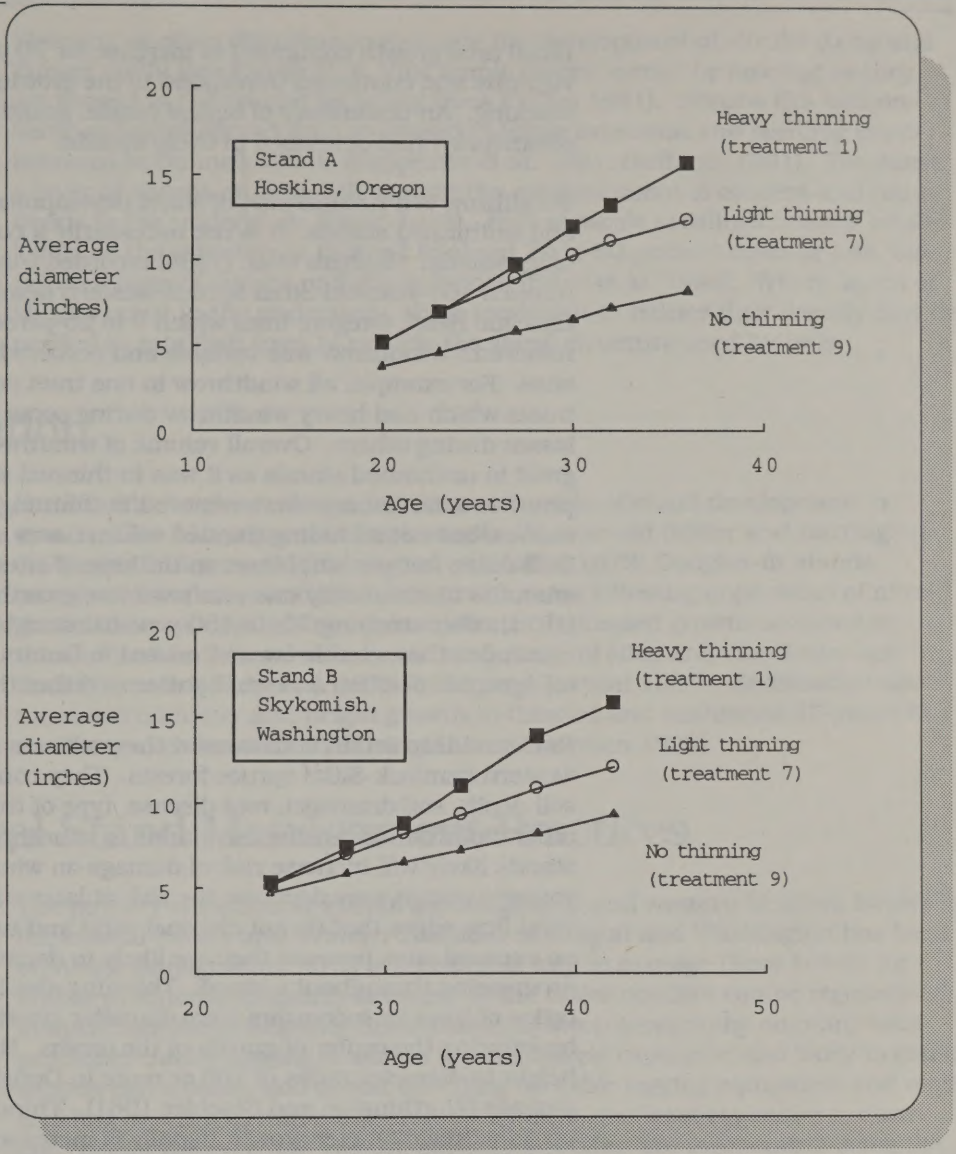


Figure G.7. *Average diameter following three intensities of thinning in two levels of growing stock studies (Curtis and Marshall 1986).*

Other work has shown that development of older Douglas-fir and western hemlock stands can be regulated by stand density control and careful thinning. Williamson and Price (1971) summarize information collected 5 to 38 years after thinning in 70-to 150-year-old Douglas-fir. Thinning intensity ranged from a control with no thinning to 55 percent of total basal area removed, and included both crown thinning (removing large trees) and low thinnings (removing small trees). Thinning reduced mortality caused by bark beetles, indicating that stand vigor was improved. Similarly, Williamson (1966 and 1982) studied growth response after thinning in a 110-year-old stand of Douglas-fir. Nineteen years after light and heavy thinnings, volume growth was nearly equal that of the control, suggesting that stands this age can be vigorous and are able rather quickly to occupy space made available by thinning. Newton and Cole (1987) reconstructed stand development to provide further evidence of the ability of thinned Douglas-fir stands to produce large trees. Stands 50 and 70 years old were thinned to less than 40 trees per acre. At time of thinning, trees were about 14 to 24 inches in diameter. Seventy years later, diameters ranged from 24 to 50 inches (average 35 to 40 inches).

Basal area growth continued to increase for 70 years, indicating that trees were vigorous and continued to respond to the growing space provided by the low stocking. An understory of bigleaf maple, grand fir, and shrubs (e.g., hazel and oceanspray) had developed in these stands.

Windthrow is a natural part of stand development which will occur in thinned and unthinned stands. It is not necessarily a concern after thinning, even in older stands. Graham et al. (1985) recorded windthrow on 400 acres of thinned 100-year-old Sitka spruce-western hemlock stands near the coast at Cascade Head, Oregon, from which 0 to 25 percent of the basal area was removed. Windthrow was variable and occurred in thinned and unthinned sites. For example, all windthrow in one tract occurred on half the plots, and tracts which had heavy windthrow during some storms had only very light losses during others. Overall volume of windthrown trees was nearly twice as great in unthinned stands as it was in thinned stands, possibly because trees prone to wind damage were removed in thinning. Total mortality from all causes, but not including thinned volume, was somewhat less on thinned sites (225 cubic feet per acre) than on unthinned sites (300 cubic feet per acre); this amounts to about only one year's volume growth. Similarly, Williams and Price (1971), after studying 70- to 150-year-old stands 18 years after thinning, concluded that windthrow was related to factors such as soil depth and topographic position and wind patterns rather than thinning.

Ruth and Harris (1979) discussed the problems of wind and thinning in western hemlock-Sitka spruce forests. They concluded that site (topography, soil depth, soil drainage), root disease, type of thinning, and age at thinning (or other disturbance) predispose stands to windthrow. Thinning old, dense stands likely will increase risk of damage on windy sites, while thinning younger stands may decrease the risk at later stages of development. Leaving wind firm edges that do not channel wind and unthinned buffers is important on exposed sites because they are likely to decrease the risk of blowdown progressing throughout a stand. Thinning also lowers height to diameter ratios of trees by increasing stem diameter growth relative to height growth and by lowering the center of gravity of the crown. Based on European experience, height to diameter ratios of 100 or more in Douglas-fir indicate susceptibility to damage (Worthington and Staebler 1961). Thinning would decrease this ratio because tree diameter growth usually is increased by thinning more than height growth is increased.

B. Understory Vegetation and Advanced Regeneration

Regulating stand density affects understory vegetation. As the overstory becomes less dense from thinning or natural disturbance, an understory of shrubs, hardwoods, conifers, and other species develops. Conifer and hardwood seedlings and saplings will grow to provide the multilayered stands used by owls. Alaback and Herman (1988) reported the development of a two-layered conifer stand 17 years following thinning in western hemlock and spruce stands. However, development of too dense an understory of hemlock may inhibit development of shrub or forb layers. After disturbance to the overstory (release), conifer seedlings and saplings increase their growth, and it appears that in open conditions the rate of growth following release is related to the size of their crowns and rates of prerelease height growth (Helms and Sandiford 1985, Gordon 1973, Stein 1981, 1986). Careful removal of overstory trees is needed to ensure release of advanced regeneration (Mann and Tesch 1985, Tesch et al. 1990a); however, Douglas-fir seedlings can recover from damage by overstory removal (Tesch et al. 1990b). Growth of western hemlock and western red cedar present in the understory of a recently thinned 110-year-old Douglas-fir stand was increased by fertilization or thinning (Harrington and Wierman 1990).

Thinning or other disturbance also aids the development of shrubs (Long and Turner 1975) (see Figure G.3). Vine maple clones spread by layering as they are pinned to the ground by falling trees (O'Dea 1991). Shrubs like salmonberry and salal spread from increased rhizome extension and seedling establishment in thinned stands (Tappeiner et al. 1991, Huffman 1991). Too dense a layer of shrubs or forbs will prevent the establishment of conifers and hardwoods in the understory (Isaac 1938). Bigleaf maple seedlings become established as the overstory is thinned to about 70 to 80 percent cover or less, but before a layer of shrubs or forbs is formed (Fried et al. 1988). Where layers of shrubs occur in the understory, some treatment to reduce their density may be needed to establish trees to provide the stand structure used by owls.

C. Fertilization

Fertilization has been shown to increase the rate of stand development in stands 15 to 110 years old. For example, 90-year-old (Miller and Harrington 1979) and 110-year-old (Harrington and Miller 1979) Douglas-fir stands increased basal area and diameter growth rates following application of nitrogen fertilizer as urea or ammonium nitrate. Increased growth occurred in thinned and unthinned stands and on a range of sites and stand ages less than 90 years (Miller et al. 1979, Miller and Tarrant 1983). Fertilization also increased diameter and height growth in thinned and unthinned 15-year-old western red cedar stands (Harrington and Wierman 1990).

D. Historical Stand Management Practices

The primary silvicultural system for Douglas-fir and western hemlock forests in the coastal forests and western Cascades of Oregon and Washington has been even-age management. This is an efficient way to manage these forests for timber production primarily because a) the major conifers can be regenerated in open conditions following disturbance, b) steep topography on many sites precludes tractor logging or makes it prohibitively expensive and likely to cause serious soil erosion, and c) cost of setting up cable logging equipment and road building in steep terrain makes it most efficient and least expensive to clear-cut. Under the even-age system, stands most often are regenerated using the clear-cutting method, followed by site preparation, planting nursery-grown seedlings, and some level of control of herbs, shrubs, or hardwoods. The shelterwood method also has been used on some sites where wind is not a serious problem (Williamson 1973).

Early in the development of silvicultural practices in this region, Kirkland and Brandstrom (1936) recommended partial cutting and group selection as a way to manage Douglas-fir. Isaac (1956) reviewed the early trials of this type of "selection management" in old-growth forests and recommended that Douglas-fir forests be managed under even-age systems. His recommendations were based on observations that a) there was little natural regeneration occurring after selection cutting, b) understory trees were damaged by logging, c) there was blowdown (few trees, but lots of volume), and d) the old trees generally did not increase their growth rates after cutting. Isaac (1956) recognized several cases where selection cutting (uneven-age management) appeared to be reasonable: a) dry sites with more open stands, b) stands with a high proportion of young trees, and c) salvage of mortality. It is important to note that his recommendations were based mainly on experience in old stands, not young stands (less than 100 to 120 years). These recommendations considered only natural regeneration without well-planned site preparation prior to planting or natural seeding, followed by vegetation control. Also, advances in logging

technology probably will allow somewhat more intricate treatments. Therefore, because of new information on harvesting and reforestation methods, Kirkland and Brandstrom's (1936) ideas of group selection, and group shelterwood and irregular shelterwood (Smith 1986, Troup 1928) should be reviewed. They can be considered for use on certain sites in young and mature forests along with green tree-retention and other "new perspective" practices.

E. Stand Simulators and Growth Models

Growth models can be used to predict the development, growth, and yield of forest stands with and without treatments. These models will predict average tree diameter, height, total stand basal area, volume, and mortality. Simulators such as DFSIM (Curtis et al. 1981), CRYPTOS (Krumland and Wensel 1980), ORGANON (Hester et al. 1989), and PROGNOSIS (Stage 1973) predict these variables for entire stands and/or by tree size classes within stands. The trends in simulated stand growth and development are consistent among these models. We used them to project the effects of different silvicultural systems on stand growth for owl habitat. When compared with data from actual stands, DFSIM and ORGANON predict trends in stand growth quite accurately (Hann 1991, Stere 1991).

The snag recruitment simulator provides a means to predict snag longevity by diameter and decay class for natural snags or those created by management. This program was developed by Bruce Marcot (PNW Research Station, Portland, Oregon) based on information in Neitro et al. (1985).

IV. Examples of Silviculture Prescriptions

Following are silviculture systems for different types of stands common throughout the range of northern spotted owls. We used data from actual stands and simulated the development of structures following treatments to grow large trees and produce multilayered stands. When actually implementing these systems the following points should be evaluated to see if they apply to the stand in question. They are suggestions which will help ensure that silviculture systems "mimic" natural disturbance and stand development. The list is not exhaustive; other ideas will be appropriate on a stand by stand basis:

- Favor some large, trees with many limbs for potential nest sites.
- Use hardwoods to help develop a multilayered stand.
- Encourage the growth of advanced regeneration of shade-tolerant conifer and hardwood species, even in young (30 to 50+ years old) stands.
- Establish new regeneration by planting or seeding in young (50+ year-old) stands after making small openings or reducing overstory density in parts of a stand.
- Consider varying the distribution of overstory trees when thinning. Vary spacing and tree density, make openings for new regeneration and release advanced regeneration.
- When thinning, leave some trees in the smaller crown size classes (intermediate and suppressed) to help promote a layered stand.
- In stands with irregularly spaced trees, consider a crown thinning to release individual trees while maintaining the irregular spacing.

A. Douglas-fir and Western Hemlock Stands

(Oliver et al .1991)

The following examples from Douglas-fir and western hemlock stands 30 to 70 years old (Oliver et al. 1991) show trends of stand development under different densities. Diagrams are drawn to scale using information from stand simulators. Stands are projected with no treatment (Figures G.8, G.9, G.10). In addition, the 30-year-old stand (Figure G.8) is projected with two thinning regimes (low and moderate density); the 70-year-old stand is projected with a thinning regime (moderate density) and a treatment to produce a multiple-canopy stand (Figure G.9). In these stands, the second story would result from release of conifers and hardwoods, or planting and seeding of conifers following thinning. Development of a young plantation is shown in Figure G.10. Here, too, thinnings stimulate large tree and early understory development. These simulations indicate that there are several advantages of manipulating overstory density to produce owl habitat:

a) The size of the average tree, and the size of the largest 5 percent of the trees in the stands, are increased. For example, the 30-year-old stand (stand B, Figure G.8) under a low density thinning regime is simulated at age 90 (year 2050) to have an average diameter of 36 inches and the largest 5 percent of the trees have diameters of about 44 inches; while Stand A, with no activity, has trees of 18-inch average diameter and for the largest 5 percent of the trees have 27-inch diameters.

b) In stands which have had trees thinned, the canopy is "deeper," and trees have larger crowns. For example, stands managed under the low-density thinning regime, at age 90 years (year 2050), have crowns estimated from about 60 to 140 feet above ground (i.e., more than 60 percent of the length of the tree will have live crown on it); while on the untreated stand crowns will be about 110 to 140 feet above ground (see Figure G.8).

c) Reducing overstory density will enhance development of an understory and encourage the development of multilayered stands typical of those used by owls (Figure G.1). Without thinning, stands may be either too dense for tree and shrub seedlings to become established, or those that are present will grow very slowly.

These stands likely will not produce large snags or logs on the forest floor naturally. Mortality due to crowding will kill trees less than 11 inches in diameter. However, stands at low density will have trees 25 inches diameter breast height (dbh) and larger, some of which will be killed by pathogens and insects, or which can be girdled or topped to make snags.

Oliver et al. (1991) predicted that the risk of wind damage to unmanaged stands is greatest when they are about 30 to 70 years old (see Ruth and Harris 1979). After about 70 years, the larger trees in the stand are likely to become stable.

The maximum possible costs and maximum possible returns for these scenarios have been estimated (Table G.1).

B. Douglas-fir from Oregon Coast Range *(Birch 1991)*

Example 1: A 60-year-old Douglas-fir and western hemlock stand, on a productive site (site index 130 feet at 50 years) with 280 trees per acre. The goal of the simulation was to produce a multilayered stand structure (similar to stand A in Figure G.11) as quickly as possible.

- At 60 years the stand was thinned leaving a) the largest 10 trees per acre (26 to 30 inches in diameter), b) trees in the smaller sizes (48 trees per

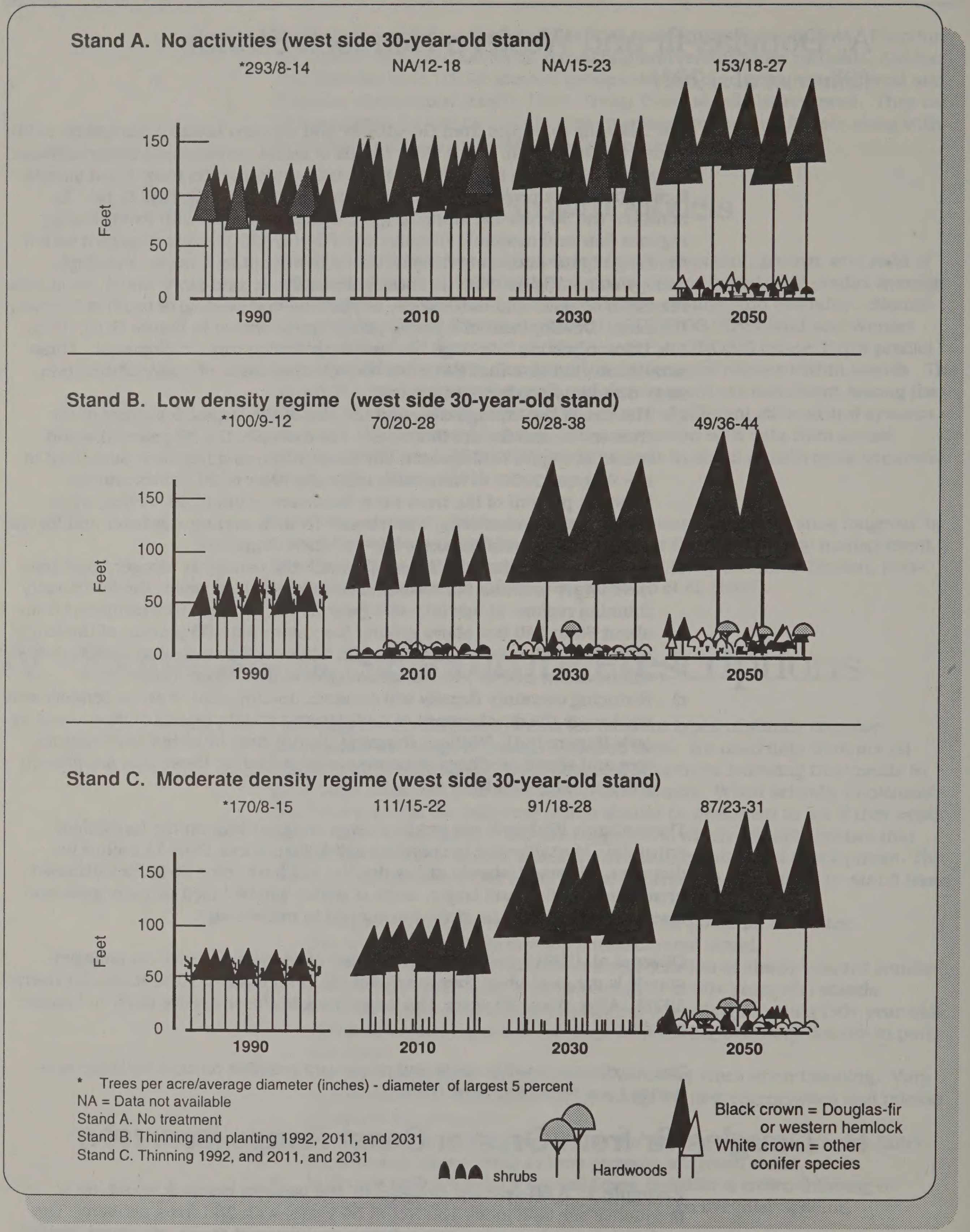


Figure G.8. A 30-year-old Douglas-fir/western hemlock stand simulated with no treatments and with development under low density and high density regimes. Numbers of trees per acre, average diameter, and diameter of the largest 5 percent of the trees are shown at each year. Note the increased crown and understory development as overstory tree density decreases (Oliver et al. 1991).

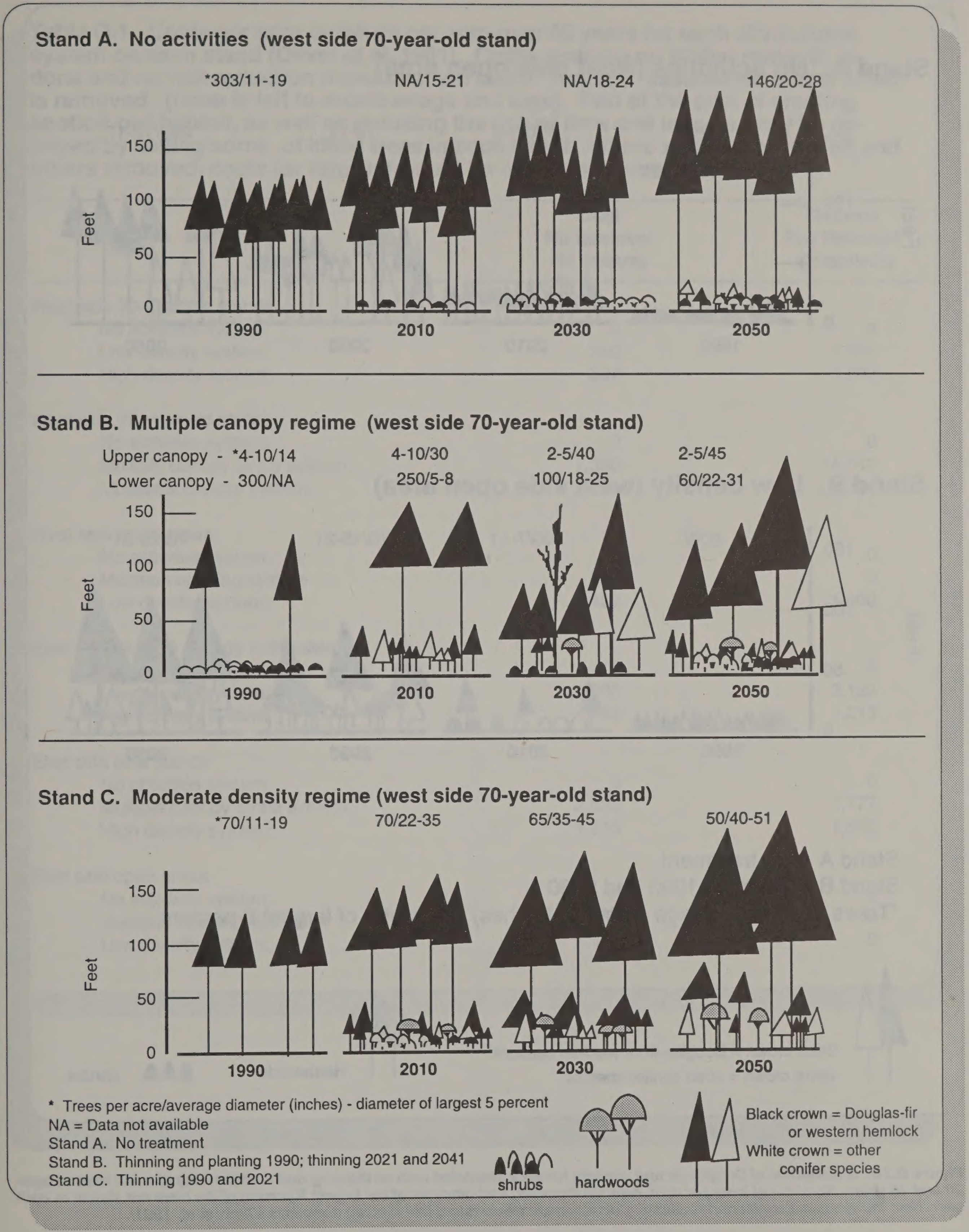


Figure G.9. *A 70-year-old Douglas-fir/western hemlock stand simulated with no treatments and with development of multiple canopy and moderate density regimes. Number of trees per acre, average diameter, and diameter of the largest 5 percent of the trees are shown at each year. Note the increased crown and understory development as overstory tree density decreases (Oliver et al. 1991).*

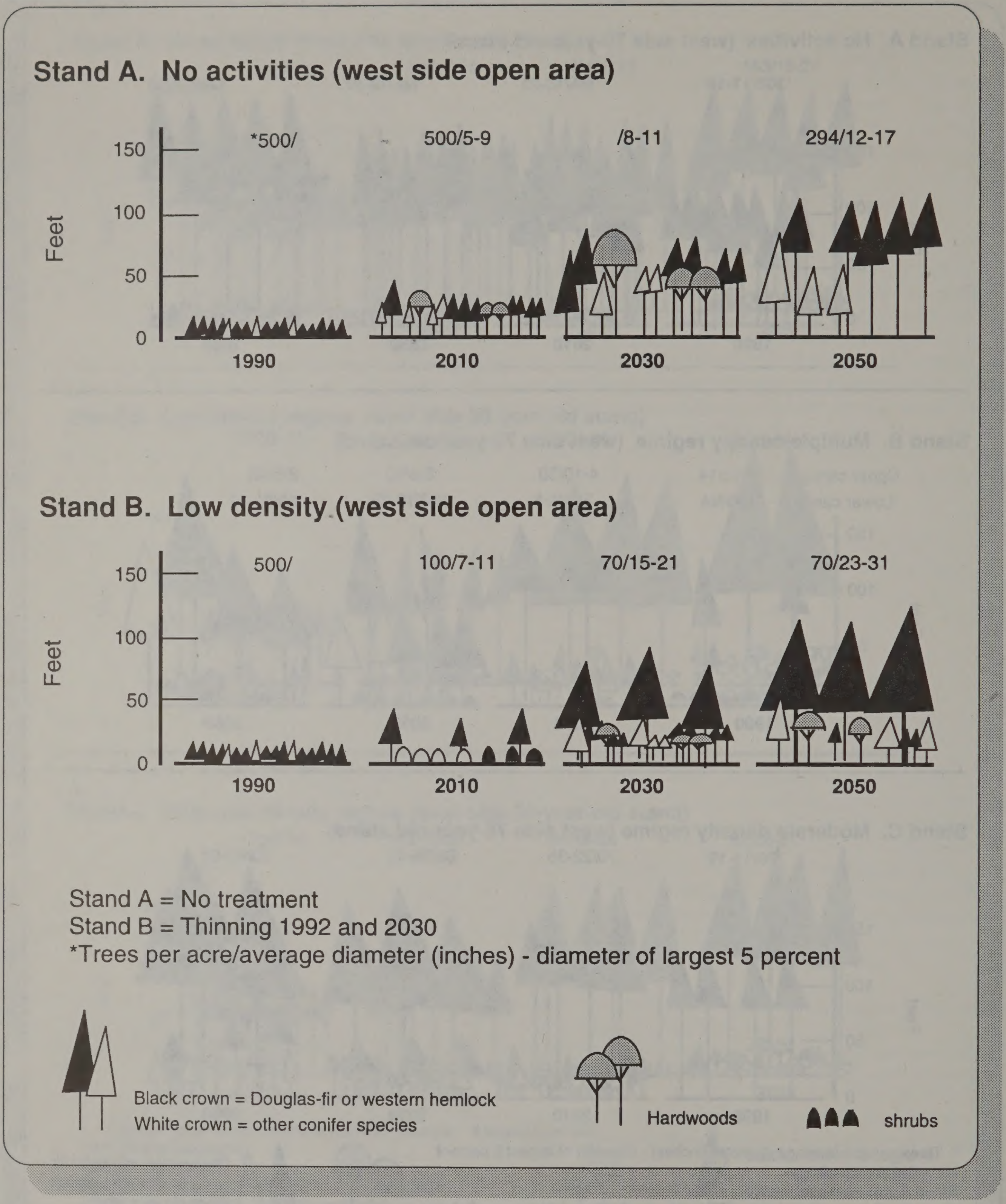


Figure G.10. A plantation of Douglas-fir and western hemlock simulated with no thinning and with thinning of small trees at ages 20 and 40 years. Numbers of trees per acre, average diameter, and diameter of the largest 5 percent of the trees are shown at each year. Note the increased crown and understory development as overstory tree density decreases (Oliver et al. 1991).

Table G.1. Costs per acre or return per acre over 60 years for each silvicultural system on each stand (Oliver et al. 1991). Costs assume no timber removal is done and no risk reduction measures are taken. Returns assume all timber killed is removed (none is left to create snags and logs). Part of the cost of creating spotted owl habitat, as well as reducing the risk of fires and insects, may be defrayed by selling some of killed trees in each stand. Where some trees are left and others removed, costs (or returns) would be between values shown here.

	Cost No Removal (in dollars)	Returns Full Removal (in dollars)
West side 30-year-old stands		
No activities system:	0	0
Low density system:	340	7,165
High density system:	337	7,900
West side 70-year-old stands		
No activities system:	0	0
Multiple canopy strata system:	1,390	14,042
Moderate density system:	771	4,866
West side open areas		
No activities system:	0	0
Maintain opening system	310	0
Low density system:	422	1,000
East side multiple canopy strata stands		
No activities system:	0	0
Low density system:	1,030	2,129
High density system:	742	1,215
East side pole stands		
No activities system:	0	0
Multiple canopy strata system:	2,822	1,777
High density system:	1,515	1,862
East side open areas		
No activities system:	0	0
Maintain opening system:	350	0
Low density system:	150	0

acre, 4 to 12 inches in diameter), and c) 10 percent of the trees 12 to 26 inches in diameter.

- Space created by tree removal was regenerated at a density of about 200 trees per acre by planting or releasing advanced regeneration.
- By age 120 years, this stand was projected to have a diameter distribution resembling those around owl nest sites (Figure G.11 Stand A). Largest trees were more than 44 inches dbh. There were more than 150 trees per acre less than 12 inches in diameter in the understory. Estimated understory height ranged from 45 feet to more than 120 feet; estimated canopy cover is 100 percent.
- Snags and logs on the forest floor might not occur naturally with this system, and may have to be made by killing live trees.

Note that the untreated stand was not projected to have developed multiple layers or have the desired structure by age 120 years.

Example 2: A Douglas-fir, grand fir, bigleaf maple stand, site index 120 feet at 50 years, with an initial density of 881 stems per acre. Since stocking was so high, this stand was simulated to have three thinnings (Figure G.11, Stand B). Hardwoods were left to develop a multilayered structure.

- At age 40 years, 50 percent of the conifers in the 10- to 16-inch diameter classes were thinned. There were 362 conifers and 114 hardwoods per acre left; 100 conifers per acre were planted.
- At age 60 years, 50 percent of the trees in the 10- to 22-inch diameter class were converted to snags, logs on the forest floor, or harvested. There were 275 conifers and 70 hardwoods per acre left; 100 conifers per acre were planted.
- At age 80 years, 60 percent of the conifers 8- to 22-inches in diameter were made into snags and down logs or harvested. There were 224 conifers and 70 hardwoods per acre left.

Removing trees or killing them for snags or down logs allowed space for development of large trees (42+ inches in diameter) and establishment and growth of an understory. No trees more than 22 inches in diameter were removed or killed for snags or down logs. At age 120 years, the treated stand was projected to have the required structure (Figure G.11, Stand B); simulated understory height ranged from 30 feet to 110 feet; canopy cover was 53 percent. Without treatment, the stand would not have a multilayered structure; understory was projected to be about 22 percent.

Example 3: Two young stands were simulated to grow without treatment until age 120 years. Stand A, which had about 230 bigleaf maple stems per acre, developed a second layer as the conifers overtopped the maple (Figure G.12). However, the understory was not nearly as well developed as the stand used for nest sites (or the managed stands in examples 1 and 2), since the second layer had fewer, shorter trees than stands used for nesting. Stand B, which had no maple, would not likely form a second story.

C. Redwood and Mixed Conifer from Northwestern California *(Thornburgh 1991b)*

This is a simulation of a redwood and Douglas-fir plantation on a productive site (site index 200 feet at 100 years). At 15 years, there are 78 redwood sprout clumps per acre (4 to 12 sprouts per clump). The rest of the stand is planted to redwood and Douglas-fir and there are natural saplings and seedlings of grand fir, western hemlock, Sitka spruce, and tanoak (Figure G.13). Also present are salal, ceanothus, huckleberry, and red alder. The goal is to

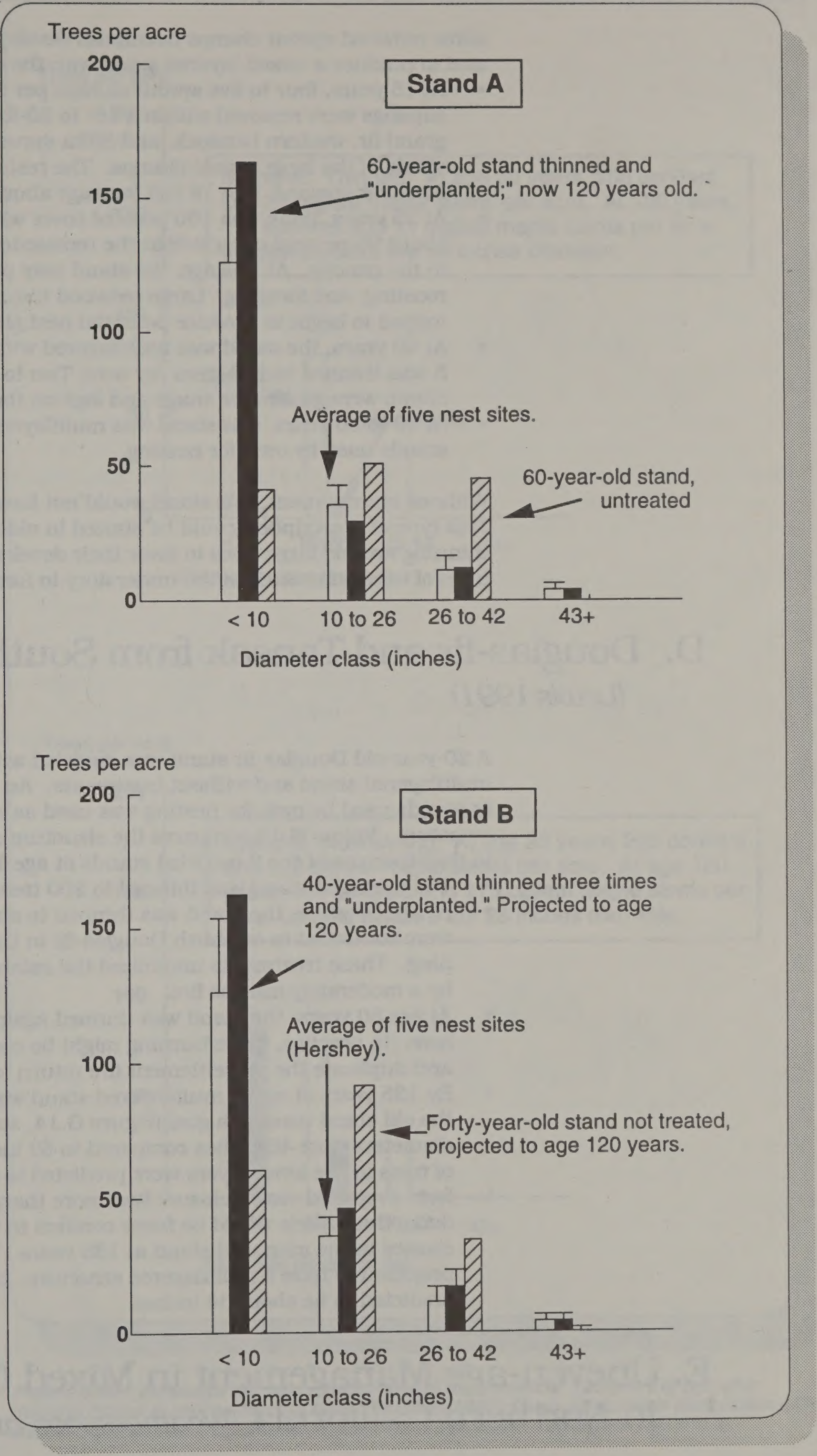


Figure G.11. *Diameter distributions for spotted owl nest sites (Hershey pers. comm.) and simulations of two stands managed to produce spotted owl habitat, and two unmanaged stands (Birch 1991).*

allow redwood sprout clumps maximum development to form an upper canopy and to produce a mixed layered stand with the other species.

- At 15 years, four to five sprout clumps per acre were selected and all large saplings were removed within a 16- to 20-foot radius. Shorter seedling grand fir, western hemlock, and Sitka spruce were allowed to grow in the shade of the large sprout clumps. The rest of the stand was thinned at an irregular spacing, 9 to 18 feet (average about 13 feet.)
- At 25 years, there was 100 percent cover within the sprout clumps, and about 95 percent cover within the remainder of the stand with some gaps in the canopy. At this age, the stand may provide cover for dispersal, roosting, and foraging. Large redwood trees in sprout clumps could be topped to begin to produce potential nest sites.
- At 40 years, the stand was multilayered within the redwood sprout clumps. It was thinned to 135 trees per acre. Two to four large trees per sprout clump were girdled for snags and logs on the forest floor.
- At 40 to 50 years, this stand was multilayered, with a structure typical of stands used by owls for nesting.

Without management, this stand would not have a well-developed understory. This type of prescription could be started in older stands using the principles of thinning around large trees to favor their development and keeping smaller trees of tolerant species in the understory to form a multilayered stand.

D. Douglas-fir and Tanoak from Southwestern Oregon *(Lewis 1991)*

A 20-year-old Douglas-fir stand was modeled with treatments to produce a multilayered stand and without treatments. An old multilayered stand similar to stands used by owls for nesting was used as a goal, or the desired stand structure. Figure G.14 compares the structure of the natural old growth stand to the structure of the 2 modeled stands at age 135.

- The managed stand was thinned to 200 trees per acre at age 20 years.
- At age 50 years, the stand was thinned to about 80 trees per acre. Tanoak were controlled to establish Douglas-fir in the openings created by thinning. These treatments minimized the establishment of openings created by a moderately intense fire.
- At age 80 years, the stand was thinned again, removing about 30 trees per acre. In practice, underburning might be considered to reduce fire hazard and duplicate the presettlement fire return interval.
- By 135 years of age, a multilayered stand was achieved which resembled the old stand used as a goal (Figure G.14, stand C). Maximum tree diameters were 40 inches compared to 52 inches in the old stand. Height of trees in the lower layers were predicted to range from about 20 feet to 80 feet. Projected crown closure was more than 70 percent. If burning were done, there likely would be fewer conifers in the 10- to 16-inch diameter classes in the managed stand at 135 years. The unmanaged stand was not projected to have a multilayered structure, and maximum diameter was predicted to be about 34 inches.

E. Uneven-age Management in Mixed Conifer Forests in Northern California *(Weatherspoon and Ritchie 1991)*

In this case, the stand was multistoried, and it was simulated under uneven-age management and use of prescribed fire for 240 years (Figure G.15). This example illustrates that uneven-age management in mixed conifer forests can

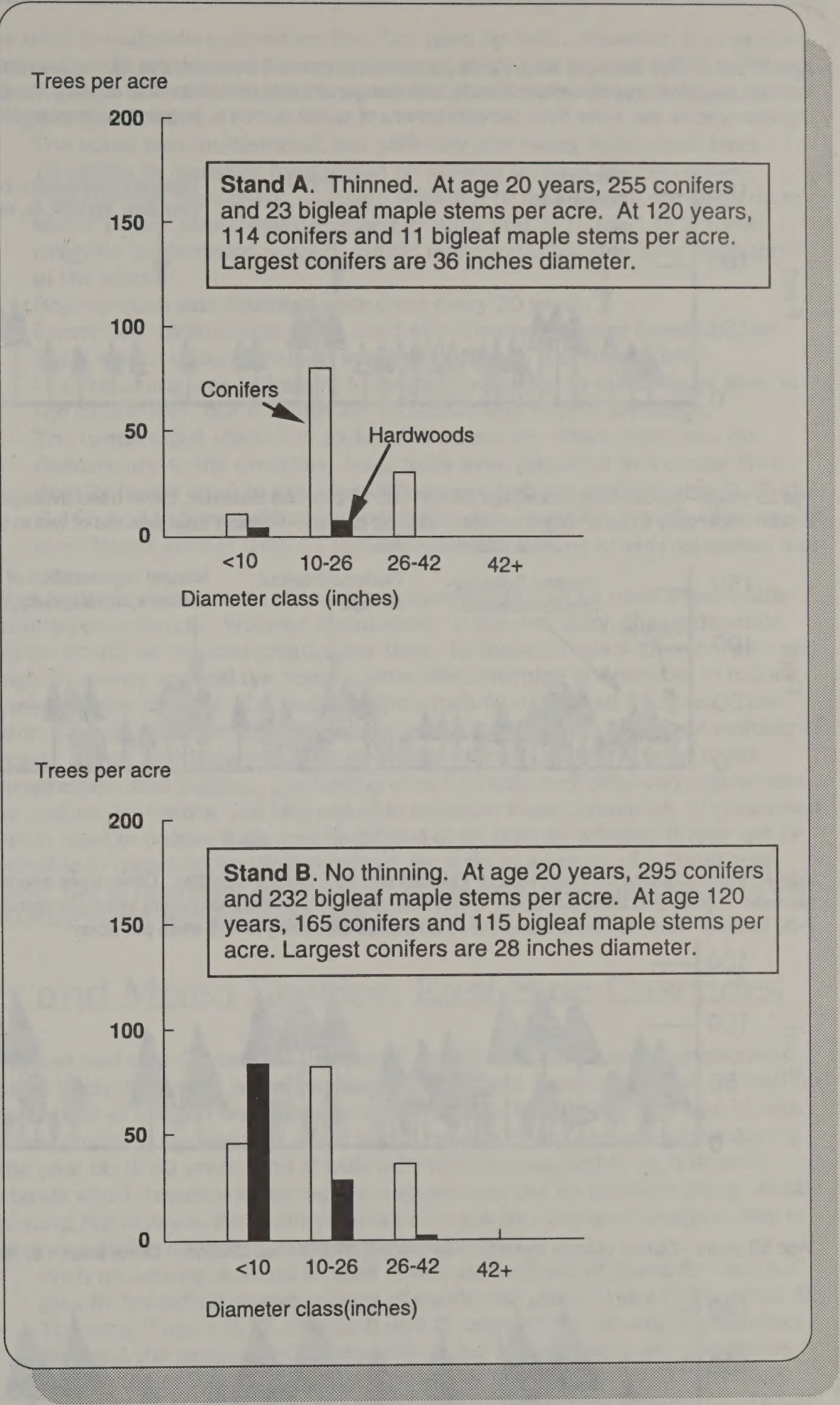


Figure G.12. *Simulated diameter distributions of two stands at 120 years of age after thinning (Stand A) and no thinning (Stand B) (Birch 1991). Compare diameter distibutions with stands thinned at later ages to obtain large trees and understory layers (Figure G.4).*

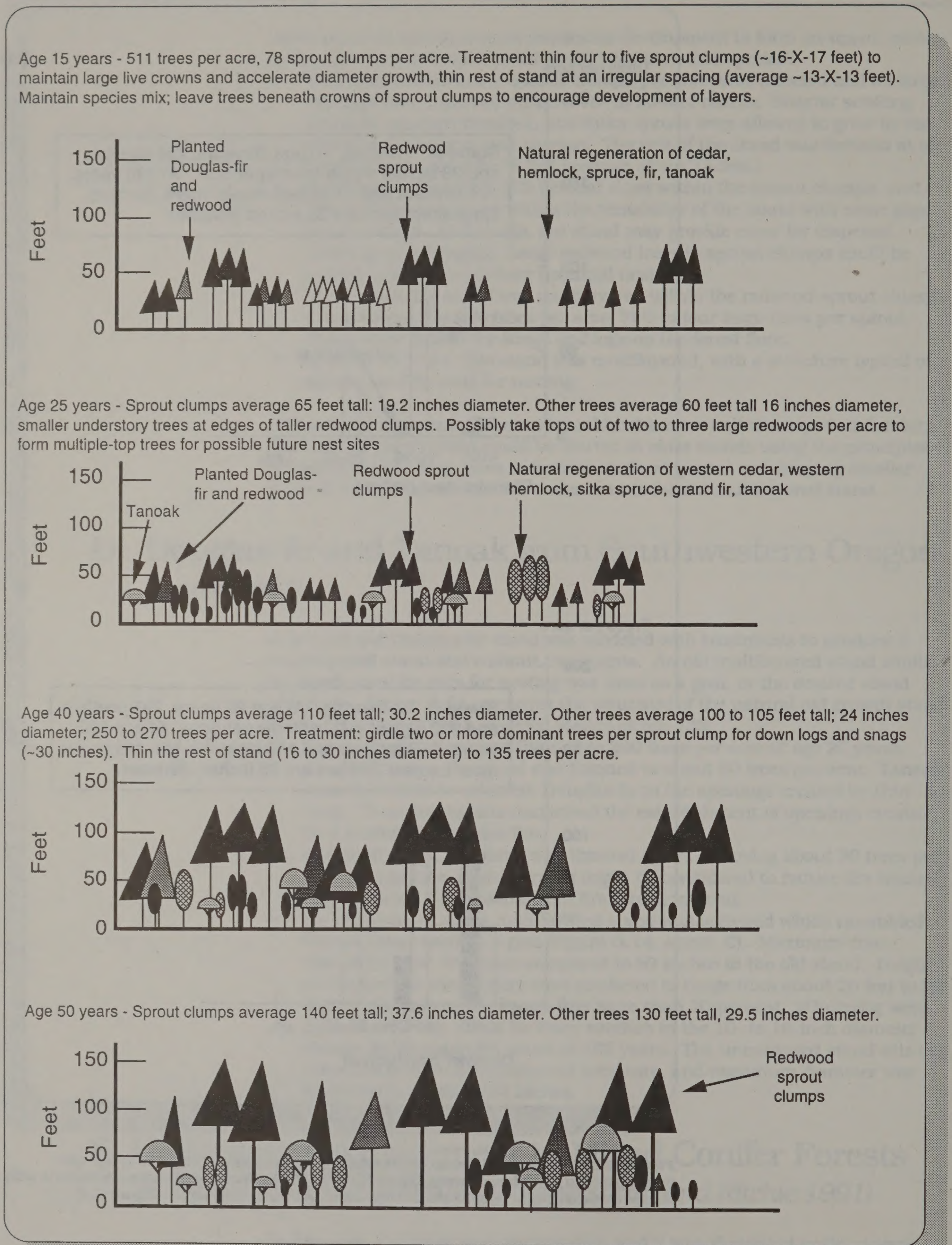


Figure G.13. *Silviculture system for producing spotted owl habitat in young-growth redwood stands (Thornburg 1991b)*

be used to maintain a structure like that used by owls. However, if prescribed fire is used to reduce fuel accumulation and risk of an intense wildfire, then it likely will be difficult to maintain a suitable structure in all parts of a stand for long periods of time.

- The stand was multistoried, but probably had many more small trees 1 to 10 inches in diameter than would be present without fire prevention.
- Two systems were used: 1) group selection to make small openings up to about 1 acre, plus thinning among groups, and 2) small (1 to 2 acres) irregular shelterwood units to obtain regeneration and to keep large trees in the stand.
- Regeneration and thinning were done every 20 years.
- Prescribed underburning was used about every 40 years to reduce fuel loads and to make the stand less susceptible to a severe wildfire. Underburning was estimated to cause a reduction in numbers of trees in the understory, but it would aid establishment of new seedlings.
- The unmanaged stand lost its layered structure. Since there was no disturbance to the overstory, large trees were projected to increase their density (basal area) to well over 300 square feet per acre (Figures G.15 and G.16), and to form a dense canopy which would inhibit growth of trees into size classes greater than 41 inches in diameter.

This example shows that uneven-age management can be used to maintain multilayered stands. Without disturbance to the overstory, the understory layers would be reduced greatly over time. In these forests with a low intensity high frequency natural fire regime, prescribed burning is desirable to reduce fuels and the chances of an intense fire which would kill all the trees. However, if fire is used, understory density is likely to be decreased for a number of years. These multistoried stands probably were not common prior to fire suppression and logging. *Controlling stand density and obtaining regeneration, as well as fire control, will be needed to maintain these structures.* If prescribed fire is used to reduce fuels and likelihood of an intense wildfire, it may not be possible to maintain an ideal structure for owls in all parts of a stand over time. Use of prescribed fire should be implemented on a landscape basis with burning varied over space and time.

F. Multilayer and Mixed Species, East Side Cascades

Typical east side Cascade multilayered, mixed species stands of ponderosa pine, larch, lodgepole pine, Douglas-fir, and grand fir are projected: a) with no treatment of a stand originated by wildfire about 80 to 100 years ago, b) with heavy thinning applied to a stand which resulted from partial cutting during the past 80 to 90 years, and c) with light thinning applied to high density stands which resulted following fire suppression but no partial cutting. *Under natural fire regimes, these stands would tend to be more open and probably to be less suitable habitat for owls (Oliver et al. 1991).*

- With no activity, a stand formed a very dense layer of grand fir and Douglas-fir beneath a sparse canopy of ponderosa pine (Figure G.17, stand A).
- Thinning (Figure G.17, stands B and C) followed by natural regeneration changed the understory to primarily grand fir and decreased ponderosa pine in the overstory. This trend probably could be reversed with heavy thinning and/or planting of pine. Trees with mistletoe brooms can be left for owl nest sites.
- Risk of severe fire was high in all three systems due to slash following treatment or self-thinning due to crowding. Fuel management and fire suppression likely will be needed to maintain these structures (Appendix F).
- Pathogens and insects killed trees of all species, added to fuel loading, and decreased the density of the overstory. Thinning and salvage under a low density scenario would help reduce effects of pathogens and insects.

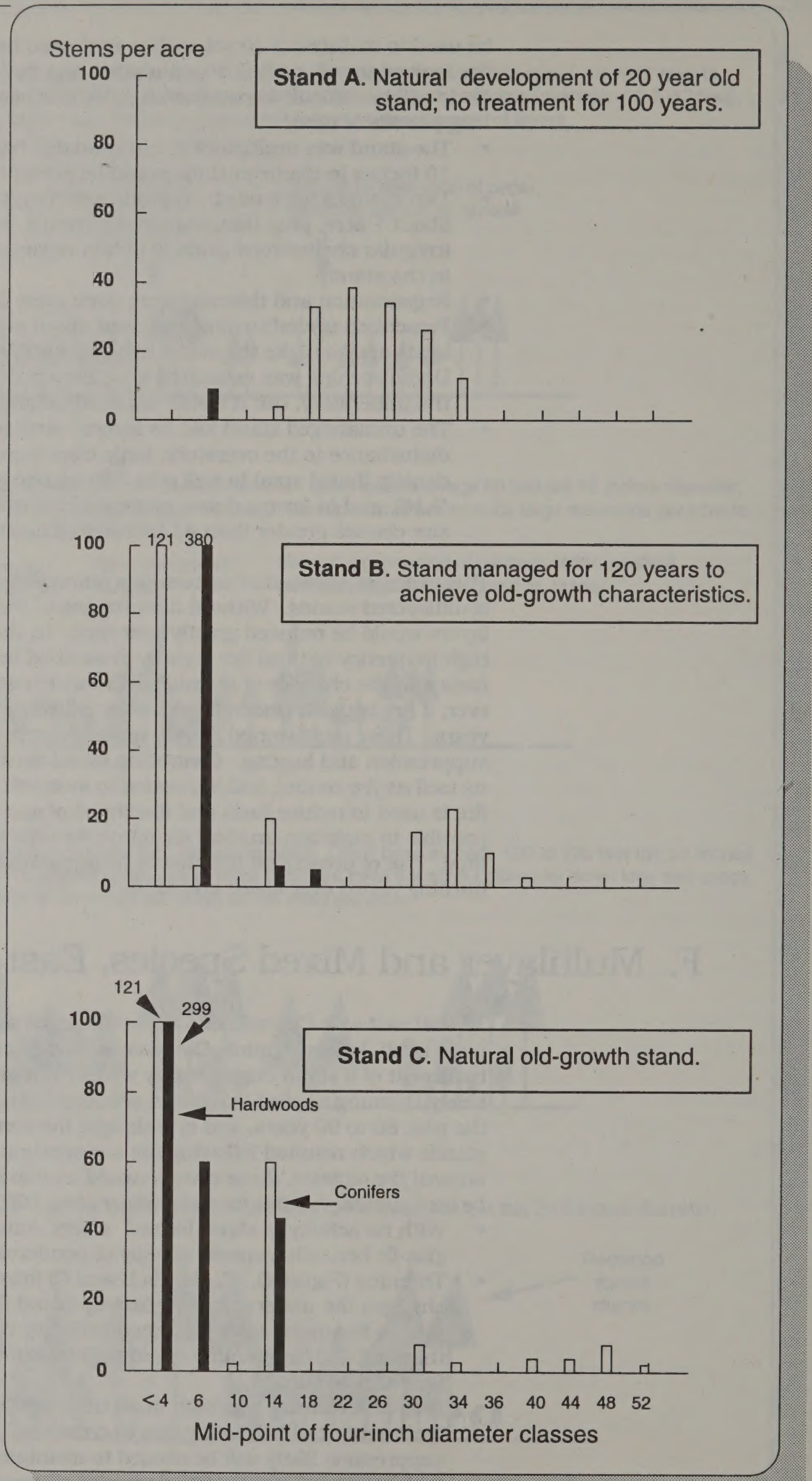


Figure G.14. A. 20-year-old stand modeled with treatments to produce old-growth characteristics at 100 years (Stand B), and at 100 years with no treatments (Stand A). Stand C is the desired stand structure (R. Lewis 1991).

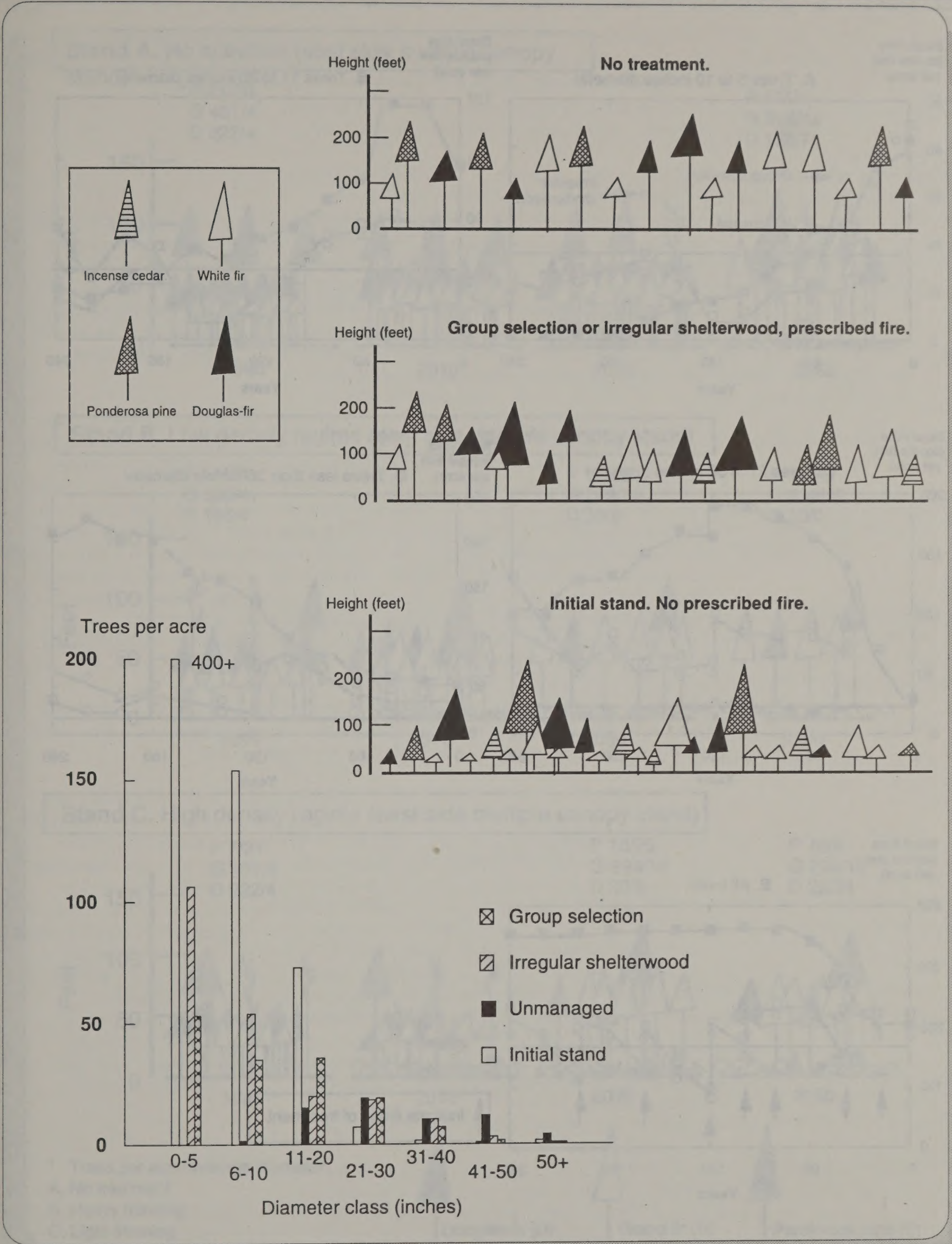


Figure G.15. *Simulations of a mixed conifer stand before management, after 240 years with no management and with uneven-age management using irregular shelterwood and group selection methods. Prescribed fires were used to reduce fire hazard in the managed stands. Drawings of stand structures above and diameter distributions below (Weatherspoon and Ritchie 1991).*

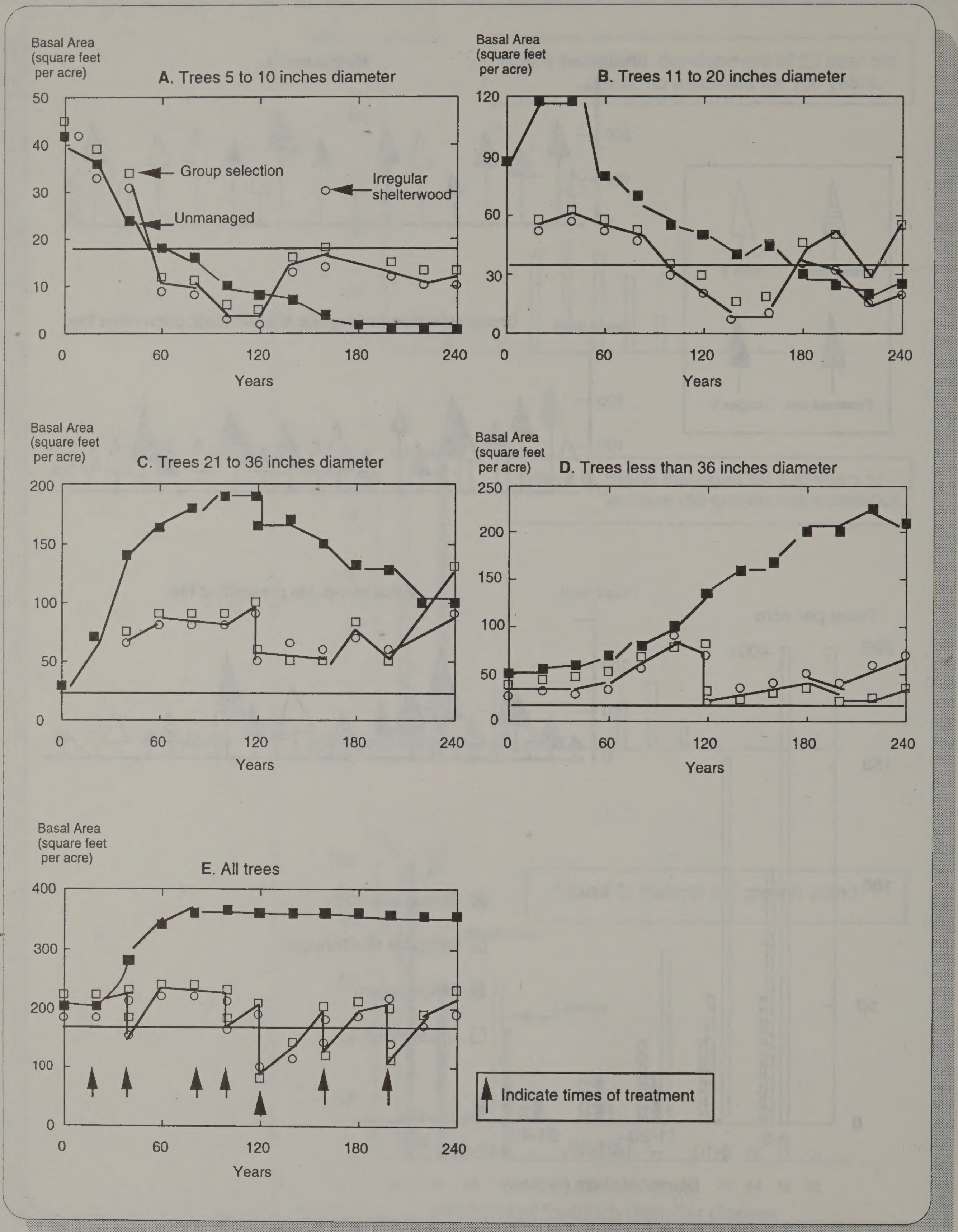


Figure G.16. *A mixed conifer stand simulated to maintain a multilayered structure through 240 years by two types of uneven-age management and prescribed fire. Diagrams show the basal area by four size classes in Stands A, B, C, and D, and for the entire Stand E. Horizontal lines indicate minimal level of basal area needed to maintain structure (Weatherspoon and Ritchie1991).*

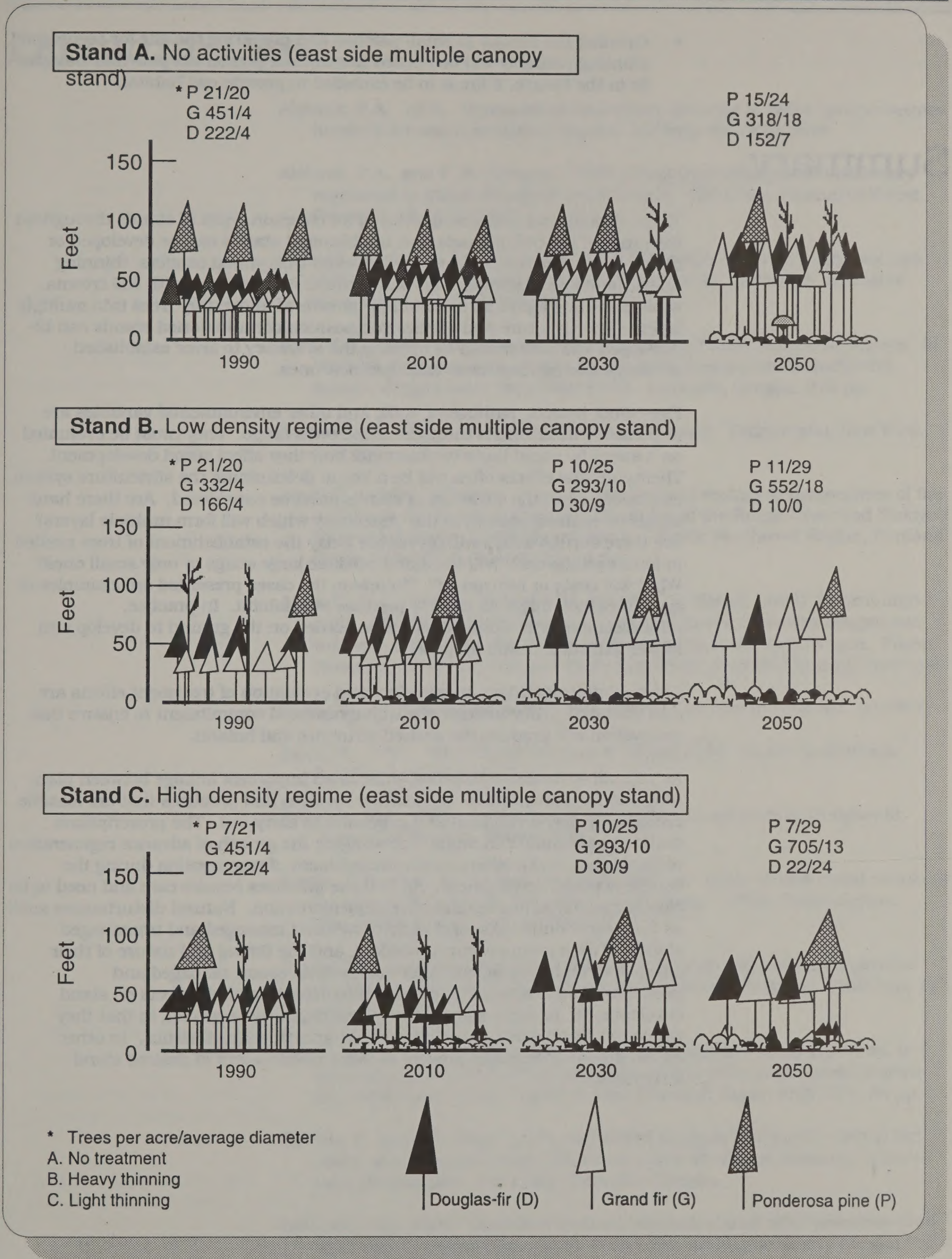


Figure G.17. *Development of a mixed conifer, multiaged stand, eastern Cascades, at different densities. Number of trees per acre and the average diameter are shown for the principal species (Oliver et al. 1991).*

- Opening the canopy in small patches and preparing the site for seeding or planting probably will be needed to maintain ponderosa pine and Douglas-fir in the forests, if fire is to be excluded to provide owl habitat.

Summary

These silvicultural systems, developed for common types of stands throughout the range of the owl, indicate that multilayered stands can be developed or maintained. Where stands are well stocked with young conifers, thinning these stands provides space for development of large trees with full crowns, while providing light and moisture for growth of understory trees into multiple layers. The structure and species composition of multistoried stands can be developed and maintained by opening the overstory to favor established seedlings and saplings or to establish new ones.

Fire, wind, insects, pathogens, soils, and other environmental variables are important within forests throughout the owl's range. They must be evaluated on a stand by stand basis to determine how they affect stand development. Their potential effects often will be a key in determining the silviculture system employed. Also, the structure of stands must be considered. Are there hardwoods or conifers present in the understory which will form multiple layers? Are there shrubs which will prevent or delay the establishment of trees needed to form multilayers? Will the stand produce large snags or only small ones? What will costs or returns be? Therefore, the cases presented are examples of systems which might be used to produce owl habitat. In practice, multidisciplinary professional input is needed on the ground to develop and implement silvicultural systems.

Careful implementation, monitoring, and evaluation of treatment effects are also essential. They indicate the willingness and commitment to ensure that the system will produce the desired structure and habitat.

As with all silviculture activities, there is an important linkage between planning and implementation. Silviculture systems and practices that are feasible ecologically may be difficult and expensive to carry out. The prescriptions outlined here call for thinning, encouraging the growth of advance regeneration of hardwoods and conifers, and establishment of regeneration during the course of stand development. All of these practices require care and need to be closely monitored during and after implementation. Natural disturbances such as fire, insect outbreaks, and windthrow affect managed and unmanaged stands. These events occur at random, and the timing and nature of their effects cannot be predicted. After such events occur, managed and unmanaged stands must be evaluated to determine their effects on stand development. In some stands, the effects might be beneficial, in that they would aid stand development toward old-growth characteristics. In other cases, disturbance might prevent or delay development of desired stand structures.

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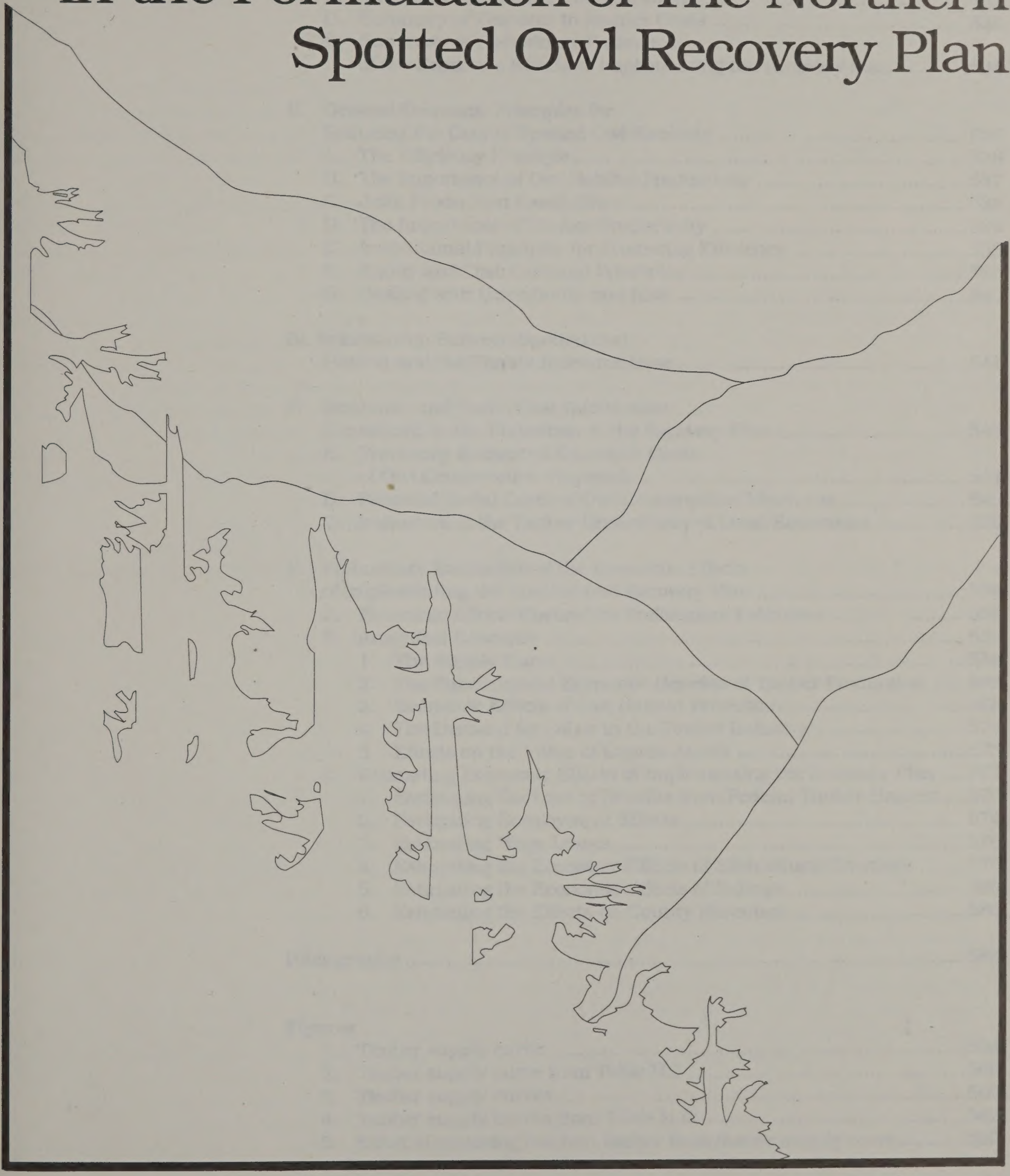
Appendix H

Economic and Social Considerations in the Formulation of The Northern Spotted Owl Recovery Plan



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I. Introduction and Summary

A. Requirements of the Endangered Species Act

The Endangered Species Act establishes a biological imperative that governs the formulation of the recovery plan for the northern spotted owl, a species that was placed on the list of threatened species on June 26, 1990. The biological imperative requires that the recovery plan provide for the management of the owl and its habitat in a manner that will result in the conditions necessary for its long-term survival without the protections of the act. If this is achieved, the species can be removed from the list. Clearly, biological principles and information will form the primary basis for designing and evaluating the likely success of management actions for recovery of the spotted owl.

B. The Problem

Formulation of a recovery plan for the northern spotted owl encounters many of the fundamental conflicts that generally arise between economic growth and productivity, on one hand, and environmental quality, on the other. The range and habitat of the owl are extensive and largely coincide with the remaining old-growth forests of the Pacific Northwest and other valuable timberlands with similar characteristics. Many of the actions being suggested to protect the owl population would substantially restrict the harvesting of timber from these forests. They also would prevent harvest from some younger forestlands that could become owl habitat in future decades. Although the preservation of owl habitat will yield a variety of benefits to wildlife and recreation, substantial social and economic costs will be caused by the reductions in timber harvests that will result from implementing such measures during many decades.

U.S. Forest Service and Bureau of Land Management (BLM) estimates indicate that planned timber sales in federal forests in the 1990s would have yielded annual timber harvests between 3 and 4 billion board feet per year, generating more than $1 billion dollars annually in economic benefits and supporting nearly 70,000 jobs in the Pacific Northwest. Projections for some owl preservation plans show that they would cause a substantial decline in production and employment in the timber and wood products industries in the Pacific Northwest. Timber harvests from federal lands would be cut nearly in half. Estimates of the costs of such proposals have ranged as high as $25 billion over 50 years (Mead et al. 1990) and 40,000 jobs (Beuter et al. 1990). The threat of such economic effects has made the preservation of the owl very controversial.

C. The Role of Economic Considerations

Secretary of the Interior Manuel Lujan, Jr., asked the Northern Spotted Owl Recovery Team to consider economic effects to the extent consistent with its legal mandate in formulating a recovery plan for the owl. The decision to consider economic effects in formulating a recovery plan represents a significant departure from past practice. Recovery plans prepared for other species have not formally used economic analysis, although the costs of management actions such as acquisition of habitat have been considered.

Several unique challenges confronted the Recovery Team because of the precedent-setting nature of this effort. On one hand, advocates of forest preservation and owl conservation expressed concerns that the consideration of economic effects would prevent the recovery plan from being based on

scientifically credible biological principles and information. Moreover, in their comments on other owl conservation proposals, forest preservation advocates have emphasized the ecological and economic benefits of owl conservation. On the other hand, advocates of timber harvesting have expressed concerns about the substantial economic costs of owl conservation and have sought ways of reducing restrictions on timber harvesting. The Recovery Team needed to develop an approach that would be responsive to the Secretary's directive while also addressing concerns on both sides of the spotted owl controversy.

Early in discussions of its task, the Recovery Team developed a conceptual approach for considering economic effects. The Recovery Team agreed that consideration of economic effects would be done in a manner that would not diminish the primacy of the biological imperative. The Recovery Team would use the best available biological information to set recovery objectives and to identify management actions to achieve recovery for the owl. Because recovery of the species is the goal of a recovery plan under the Endangered Species Act, the Recovery Team decided not to consider whether, in light of the costs and benefits of achieving recovery, a less costly goal should be pursued.

The Recovery Team recognized, however, that different combinations of management actions could satisfy the biological imperative to provide for the long-term survival and recovery of the owl. Because different management actions have different costs, it should be possible, at least in principle, to find a combination of management actions that would satisfy this biological imperative at least cost. Because of the substantial costs of protecting the owl and their effects on the well-being of people economically dependent on timber harvests in the Pacific Northwest, it was appropriate to make a concerted effort to reduce the costs of achieving recovery for the owl.

In light of the biological imperative and the desirability of reducing the costs of recovery, the Recovery Team sought an approach that would provide a reasonable and appropriate consideration of economic principles and information as well as the best biological information available. It decided to use biological principles and information to design management actions that would contribute to achieving recovery while considering economic effects in a manner that would focus thinking on ways to achieve recovery at lower costs. This common sense approach is like the efforts of a family to decide what sorts of products meet their needs and then to shop for the least costly source of those products. It is also consistent with generally accepted principles of public policy.

The approach used by the Recovery Team also was designed to meet the needs of the biologists on the Recovery Team who were responsible for formulating the owl conservation measures in the plan. Decisions regarding owl conservation options to be considered and the design criteria for those options were based on biological considerations. The economic information developed for use by the biologists and other Recovery Team members was limited to fundamental economic principles and simple indicators of the most important economic effects. This economic information was designed to be understandable to biologists and other Recovery Team members with little or no training in economics.

The information summarized in this appendix differs in several ways from a comprehensive, systematic cost-benefit study of options for achieving recovery. First, it was designed primarily to facilitate design of a cost-effective recovery plan rather than to provide information to be used by decision-makers considering whether to implement the resulting plan. Further information collected during the period of public review of the draft recovery plan will be used to develop a more complete assessment of its costs and benefits. This assessment will be available for consideration in making final decisions about implementation of the plan.

Second, the analysis in this appendix focuses primarily on the costs of owl conservation measures because they are central to the development of a cost-effective recovery plan. It does not assess the benefits of recovery because the Recovery Team did not pursue options that would fail to achieve recovery. The Endangered Species Act required the Recovery Team to focus on the question of how to achieve recovery, not whether efforts to recover the spotted owl are justified by the benefits of preserving the species and its habitat. The other benefits of various owl conservation measures, such as protection of other species and increased recreation value, were considered only when they would affect the design of the plan. They would be relevant, of course, in making final decisions about implementation of the plan.

In addition, the economic analysis used in the formulation of the draft recovery plan was not intended to provide a highly precise and comprehensive enumeration of all of the economic effects of owl conservation measures. The approach used was to be selective and "economical" in the conduct of economic analysis. Analysis was limited to key indicators of the costs of owl conservation that would be understandable and helpful to the Recovery Team's biologists in their efforts to find ways to reduce the costs of achieving recovery.

D. Summary of Features to Reduce Costs

Part of the process of formulating a cost-effective recovery plan is to consider a wide variety of ways to reduce costs without undercutting the effectiveness of the plan. This appendix outlines economic principles and information suggesting many ways of reducing costs that the Recovery Team considered. Some were rejected for biological reasons, others for lack of demonstrated application and lack of the data needed to implement them in designing a recovery plan.

Several features, however, were included in the recovery plan as a result of efforts to reduce the costs of achieving recovery. These include the following:

1. The designated conservation areas (DCAs) were designed to make use of areas that have relatively high quality owl habitat and, where possible, to avoid the use of forest with high potential for timber harvest.

2. To promote greater efficiency, the DCA boundaries will be refined prior to approval of the final recovery plan based on the site-specific data available to the federal forest management agencies.

3. The DCA management guidelines allow silvicultural treatment of areas not suitable for owl habitat to promote more rapid development of suitable conditions and provide timber as well.

4. The management guidelines for federal land outside of DCAs were tailored to local conditions so that the resulting timber harvest restrictions will better assure the habitat conditions in each area that are needed for recovery without incurring unnecessary cost.

5. Suggestions were developed for management of nonfederal lands that will increase the efficiency of their contribution to recovery by integrating state authorities and existing programs into a coordinated strategy.

6. To provide a basis for improving the cost-effectiveness of the recovery plan, a research and monitoring program is proposed to provide information on the habitat conditions that are most productive for owls and the forest management practices that are most compatible with production and maintenance of owl habitat conditions.

E. Summary of Preliminary Estimates of the Economic Effects of Implementing the Recovery Plan

Preliminary estimates of the economic effects of the draft recovery plan are included in this appendix. They were developed to provide an early basis for comparison between the draft recovery plan and other owl conservation and forest preservation proposals. To provide a consistent basis for such comparisons, the estimates were developed using the same estimation methods applied by the U.S. Fish and Wildlife Service (FWS) in evaluating the effects of the critical habitat designation for the spotted owl. These estimation methods are summarized in section IV. and are described in more detail in *Economic Analysis of Critical Habitat Designation Effects for the Northern Spotted Owl* published by the FWS at the time of the critical habitat designation (USDI 1992).

There are several important limitations in the preliminary estimates provided for the draft recovery plan. The most important limitation is that these preliminary estimates do not reflect site-specific assessments of the timber potential of the forestland included in each of the DCAs. In addition, they do not provide sufficiently precise estimates of the timber harvest and economic benefits from the salvage and silvicultural activities allowed in the DCAs. The Recovery Team will work with the management agencies during review of the draft recovery plan to develop timber harvest estimates based on more site-specific information.

The preliminary estimates do not include measures of the benefits of implementing the recovery plan. Nor do they reflect the potential increase in private timber industry harvest in response to the higher timber prices that are likely to result from implementing the plan. Such effects are analyzed in the FWS's economic analysis of the critical habitat designation and will be reflected in estimates prepared for the final recovery plan.

Implementation of the recovery plan would reduce future annual timber harvests in the federal forests of the Pacific Northwest below the levels that would otherwise occur. It is estimated that the network of DCAs would reduce mid-1990s timber harvests by 1.3 billion board feet per year in comparison to the levels that would occur under federal agencies' plans. This reduction in federal timber harvest is expected to reduce the economic benefits of timber harvest by about $470 million per year over the next 20 years or more . Employment levels in the timber industry are estimated to decline by 18,900 jobs as the industry shrinks to a size appropriate to lower harvest levels. Employment levels in related sectors also will decline by an estimated 13,200 jobs. The displacement of workers and their reemployment at generally lower wage levels are estimated to cause wage losses of $1.4 billion during the next 20 years.

Further reductions in timber harvest will result from protection of habitat in the areas outside DCAs, on federal and nonfederal land. No estimates of these reductions have been made at this time, but estimates will be prepared for the final recovery plan. Previous studies have shown that similar policies proposed by the Interagency Scientific Committee (ISC) would reduce annual federal timber harvest in areas outside of the habitat conservation areas (HCAs) by about 0.7 billion board feet. The reduction in federal harvest outside of the DCAs is expected to be of similar magnitude.

Several features of the draft recovery plan will tend to offset the economic effects of restrictions on federal timber harvest. First, the recovery plan allows silvicultural treatments within DCAs if they are designed to promote the development of habitat conditions suitable for owls in areas that are not

currently suitable. Rough estimates of the possible effects of these activities show that treatment of 50,000 acres per year could support about 600 jobs and yield about 100 million board feet of timber per year worth about $26 million.

The second feature that will tend to offset the effects of timber restrictions is allowing limited timber salvage in DCAs. Timber salvage on federal forests averaged more than 600 million board feet per year during the 1980s. In light of the fact that DCAs contain approximately one third of the forestland available for timber harvest, salvage of 10 to 20 percent of the salvageable timber within DCAs could yield, on average, 20 to 40 million board feet per year, supporting about 315 to 630 jobs.

Furthermore, other sources of timber supply, including private forestlands in the Pacific Northwest, may increase production in response to higher timber prices. Although the response in the Northwest is likely to be limited and probably could not be sustained more than a few years, it would slow the rate of job displacement in the early years of recovery plan implementation.

In reviewing these estimates of the economic effects of implementing the recovery plan, it is important to note that they reflect the future effects of all northern spotted owl conservation on federal land, not just the protection added to the current management regime by the recovery plan. The estimates were prepared in this way because the recovery plan will provide a comprehensive basis for all owl conservation efforts. Thus, these estimates attribute to the recovery plan all of the economic effects of owl conservation that occur after implementation of the plan.

If the recovery plan is not implemented, other owl conservation measures will remain in effect that also will restrict timber harvests. In particular, the Forest Service and the BLM will continue policies they developed in response to the ISC's recommendations. In addition, the FWS has designated critical habitat for the spotted owl and will apply the Endangered Species Act prohibitions against federal actions that would adversely modify critical habitat or jeopardize the species. Comparable estimates of the economic effects of these policies are presented in the *Economic Analysis of Critical Habitat Designation Effects of the Northern Spotted Owl* prepared by the FWS. Comparison of the economic effects of these policies and those proposed by the draft recovery plan are provided in section IV. That section presents more detailed estimates of the economic effects of the recovery plan and comparisons of these estimates with other owl conservation activities and proposals.

II. General Economic Principles for Reducing the Cost of Spotted Owl Recovery

The Recovery Team began its efforts to find ways of achieving recovery at lower cost by reviewing general principles of economics that deal with costs and efficiency. To identify a wide range of possibilities for reducing costs, the Recovery Team considered the application of these principles to a variety of owl conservation measures. This section summarizes the principles and applications to spotted owl recovery that the Recovery Team considered. The draft recovery plan includes some, but clearly not all, of the possible applications of these principles.

A. The Efficiency Principle

The efficiency principle can be simply stated: people in the United States will have higher incomes and a higher standard of living if the goods and services they want, including environmental quality and the preservation of species and ecosystems, are all produced efficiently.

The American people want many things. Most consumers recognize that they can get more from their family budget by shopping to find the things they want at lower prices. Business managers know that they can make higher profits by reducing the costs of their business operations or by increasing the total value of their output without proportionally increasing costs. Though imperfect, market-based economic systems have proven capable of providing people with more of what they want than other economic systems. An important reason for this success is the incentives the market creates to reduce costs. Reducing costs is one way that our economic system solves conflicts among the many different opportunities to use each resource.

Our desire for secure and increasing incomes and material well-being often appear to be in conflict with our desire for protecting the environment. Economists, however, do not see this conflict as inherently different from the conflict between, say, using iron to construct office buildings and using iron to manufacture cars. More of both buildings and cars can be produced if proper care is taken to reduce the costs of the iron used in building construction and auto manufacturing. Similarly, higher environmental quality and greater material well-being can be produced if proper care is taken to reduce the costs of environmental protection as well as the costs of economic production.

The same principle applies to owl recovery. The conflict between achieving recovery for the owl and realizing the economic and social benefits from a greater supply of timber can be reduced by implementing forestland and habitat management practices that yield a viable owl population at lower total cost.

In general, achieving recovery of the owl requires the preservation and development of owl habitat that will support an owl population of sufficient number and appropriate spatial distribution despite random catastrophic events such as fire and disease. Much of the existing owl habitat is land with old-growth forests that are prime for harvesting. Additional owl habitat can be grown by letting younger forests continue to grow and age. Thus, the preservation and development of habitat will require restrictions on the harvesting of timber from forestlands that are now suitable owl habitat as well as from forestlands that are likely to develop into suitable owl habitat.

The primary economic costs of achieving recovery result from the loss of the economic benefits from the timber that otherwise would be harvested and from the resulting increases in the prices of goods that are produced from timber. Economic benefits arise from timber harvesting because logs have a higher economic value than the costs of producing them. The economic benefits from harvesting timber are mostly captured by the owners of forestlands. For federal lands, the profits are captured by the Forest Service and the BLM and are shared with states and local communities.

The primary social cost of owl conservation measures is the decline in the quality of peoples' lives that results from the unemployment and reduced income caused by foregone timber harvests. These social costs are generally most severe in small, isolated communities with a large portion of the population employed in the timber and wood products industry. Small businesses such as sawmills and supply businesses may fail, causing loss of assets and income. People in these communities have less opportunity to find new jobs at similar wages than people living closer to urban areas with a more diversified economic structure.

The general principle for reducing the economic and social costs of owl recovery is to employ management actions that will produce a higher "yield" of owls (the number of owls supported) per unit of foregone timber production and its benefits, particularly near communities where timber workers are less able to shift to other employment.

B. The Importance of Owl Habitat Productivity

A recovery plan that uses habitat having higher productivity for owls should be able to achieve recovery using less habitat (assuming other biological requirements for recovery are met). Identifying the characteristics of habitat that are best for owls and finding ways to enhance owl habitat productivity, especially in areas that currently are not suitable habitat, may help to reduce the costs of recovery.

The high cost of owl preservation results from the large area of forestland with old-growth characteristics that is needed to provide sufficient habitat to support a viable owl population. The productivity of owl habitat is measured by the density, reproductive success and individual survival rates of the owl population that it is capable of supporting. Owl habitat productivity varies substantially and depends highly on local conditions as well as the general structure of the forest landscape. Other things being equal, the costs of achieving recovery for the owl will be lower if the areas used as owl habitat are capable of supporting more owls per acre.

Measures that increase owl habitat productivity also may help reduce recovery costs. For the overall cost of recovery to be reduced, the cost of implementing measures to increase owl habitat productivity must be less than the economic benefits gained from the additional timber that can be harvested because of the increased owl habitat productivity.

If ways can be found to improve the capability of currently existing and newly developed owl habitat to support the owl population, then less forestland will be needed to sustain the population and more forestland can be used for timber production. This may reduce the long-run costs of achieving recovery for the owl.

Research on owl ecology may help to identify environmental conditions that promote higher owl productivity. Experimentation with various silvicultural

practices may be able to show how such conditions can be created or improved in the forestlands reserved for owl habitat. Each measure for increasing owl habitat productivity should be evaluated to determine whether it would cost less than the economic benefits from the additional timber harvest that could be allowed if it were implemented. If those measures that cost less are implemented, the total cost of achieving recovery will be reduced.

It appears that, in general, the total area and connectivity of owl habitat will need to be increased to achieve recovery. Some younger forestlands that do not currently provide good owl habitat will need to be added to the overall landscape devoted to the owl. Measures that accelerate the development of younger forestlands into good owl habitat may be able to promote more rapid recovery and reduce the amount of forestlands that must be reserved to achieve recovery.

It also may be possible that, as new habitat is added, some areas of old-growth devoted to support of the owl population early in the recovery process can be harvested, perhaps by using selective harvest techniques instead of clear-cutting. As younger forests develop into suitable habitat, they could be substituted for equivalent old-growth areas previously reserved for the owl. Timber harvest could then occur in the old-growth areas that had been replaced instead of in younger forests with lower timber yields. To the extent that the economic benefits from harvesting timber in the younger forests would have been lower than in the old-growth that could be harvested, this process would reduce the total cost of recovery.

C. Joint Production Possibilities

A recovery plan may be able to achieve recovery at lower cost by preserving or producing owl habitat areas that also contribute to the preservation of other species that are candidates for being listed as threatened or endangered and need similar conservation measures. If timber harvest will need to be restricted to preserve other species as well as the owl, there may be opportunities to reduce the total costs of wildlife preservation by using areas capable of supporting a variety of species rather than using separate habitat areas for each species. Economists regard such opportunities as joint production possibilities.

A recovery plan also may be able to achieve recovery at lower costs by preserving or producing owl habitat areas that contribute to the provision of valuable services, such as recreation. Recreation is an important use of forestland, one that has brought increasing demand for restrictions on timber harvesting. There may be opportunities to reduce the total cost of providing forestland for habitat and recreation by identifying areas where the opportunities for joint production are greatest.

In the long run, it may prove possible to provide owl habitat using measures that also provide for the growth and harvest of timber in the same areas. Although much attention has been focused by previous plans such as the ISC's strategy on the prohibition of all timber harvest in owl habitat areas, selective harvesting of timber in existing suitable habitat may be able to provide timber while also preserving essential habitat conditions. If the effectiveness of such practices can be demonstrated, these selective harvesting practices can be used to reduce the economic and social costs of achieving recovery. Such possibilities need to be identified and tested to determine the extent they can be used to reduce the total cost of owl recovery.

D. The Importance of Timber Productivity

To the extent that a recovery plan uses forestland of lower timber productivity for owl habitat, it can achieve recovery at lower cost. Ideally, the total cost of a recovery plan would be minimized by selecting owl habitat areas having the highest ratio of owl habitat productivity to timber productivity as long as those areas also met the established recovery objectives.

Northern spotted owl conservation proposals have raised great controversy because of the unfortunate coincidence between owl habitat and high value timber. Nevertheless, there are clearly variations in the value of the timber inventory and in the future timber growth that can be achieved on different sites. Location and slope as well as the timber inventory affect the value of the existing timber on a site. Soil conditions and rainfall affect the rate of regeneration and regrowth of timber once a site has been harvested. In principle, use of areas with lower value timber and lower quality sites as owl habitat would reduce the costs of achieving recovery, assuming that such areas provide appropriate and sufficient habitat for owl recovery.

E. Institutional Principles for Promoting Efficiency

Economists have been able to identify the characteristics of institutions that tend to achieve high efficiency. The Recovery Team considered several of such principles in formulating the recovery plan.

Institutions tend to achieve higher efficiency when they:
- Use incentives to reward performance that improves the achievement of objectives,
- Achieve an effective balance between central guidance on goals and objectives and decentralized decision-making,
- Allow a diversity of approaches reflecting differences in local conditions,
- Provide flexibility to adapt to changing conditions and to improve quality and efficiency by responding to information about the effectiveness and cost of various actions,
- Specialize in closely related activities,
- Participate in trading or market transactions that promote the highest value use of resources.

Experience with market mechanisms shows that resource managers respond more efficiently to incentives than to directives and restrictions. The Recovery Team looked for opportunities to create incentives for improving owl productivity within each of the ownership and management regimes with jurisdiction over owl habitat.

Field level forest managers and biologists often have knowledge of local conditions that is not reflected in formal data available to their headquarters' organizations. Using this local knowledge, they may be able to identify the most productive habitat and make significant increases in the owl productivity and timber harvests on the lands within their jurisdiction.

If information on the effectiveness of various forest management practices that can enhance the productivity of owl habitat can be provided to local forestland managers and biologists, they may be able to better identify areas within their jurisdiction with the greatest carrying capacity and apply management actions that would best enhance that capacity. Allowing greater diversity in designating and managing owl habitat also may increase the chances of finding new, innovative measures for increasing owl productivity.

Economic patterns show the efficiency of specialized organizations. In the case of owl conservation, specialization may facilitate increases in owl productivity. It may be possible to create specialized elements within existing organizations for the express purpose of managing owl habitat. In some cases, changes in land ownership may be needed. Because protection of the owl population is a public good, not a market good, it would be reasonable to rely more on public than private institutions for the provision of owl habitat.

Management systems that allow trading of resources among managers of competing uses have proven to be more effective at allocating resources among those competing uses in a cost minimizing way. This principle has gained wider recognition in environmental policy in recent years. For example, applications of trading processes are being developed for air emission reduction as well as wetlands preservation and restoration. Similar trading mechanisms may be able to contribute to reducing the costs of allocating forestland to owl recovery. For example, government agencies might be allowed to trade forest-land outside of areas designated for owl habitat for areas within designated areas if they can show that there will be gains in the support of owls and timber harvests.

F. Equity and Distributional Principles

In its efforts to gather information on the costs of owl conservation measures the Recovery Team learned of the strong concerns in timber dependent communities about the unfairness of the burden they may be forced bear so that the owl can be preserved to the benefit of all. As a result, the Recovery Team developed a number of principles dealing with equity and distributional issues.

It may be possible to reduce the social costs of achieving owl recovery by slowing the rate of decline in timber harvests near the most isolated, timber dependent communities. The job losses that result from restricting timber harvests cause more severe wage losses and other social costs in isolated, timber dependent communities. If ways can be found to lessen the reduction in timber harvests near such communities, especially in the near term, the social costs of owl recovery may be lower. It also may be more equitable to compensate individuals who bear the cost of owl conservation measures by shifting more of the cost to the general public. Compensation has the added advantage of reducing the social costs by offsetting income losses that often cause socially damaging behavior without causing similar costs among the broader population from which the compensation is drawn.

G. Dealing with Uncertainty and Risk

Both policy uncertainties and scientific uncertainties affect the costs of owl conservation measures. Policy uncertainty increases costs by encouraging harvesting of timber before it has reached the age at which it would yield greatest profit. Policy uncertainty also is likely to dampen investments in increased forestland productivity. Scientific uncertainty about owl ecology and the effects of various forest management practices increases costs by requiring habitat protection measures in the short term that may be more restrictive than are needed in light of subsequent research. However, past experience shows that it also can be costly when research shows that greater protection is needed because past forest management practices did not provide adequately for the owl.

Investments that would improve the timber productivity of forestlands are discouraged by the uncertainty regarding whether the additional timber supply that results will be available for harvest or whether it will be unavailable owing to future owl conservation measures. Thus one aspect of providing incentives to increase timber growth, especially on private lands, is to reduce this uncertainty. Policies that make clear what forestland can be harvested and when will reduce the uncertainty that impedes investment.

Various forest management practices have the potential to increase the productivity of owl habitat or to allow some timber harvest within owl habitat with less damage to its value as habitat. Uncertainty about the effects of such practices prevents their use and increases the costs of owl conservation.

III. Relationship Between Spotted Owl Habitat and the Timber Resource Base

The high costs of protecting northern spotted owl habitat result from the fact that its range largely coincides with the most valuable timber resources on the forestlands of the Pacific Northwest. Spotted owls appear to concentrate their activities in old-growth stands or in mixed-age stands with both old-growth and mature trees. Recent owl surveys have located owls in a wide variety of habitat conditions. However, until research has shown that owl populations can thrive in areas that do not have classic old-growth characteristics, old-growth stands will be needed as the primary source of the owl habitat needed to assure its survival and recovery.

Northern spotted owls not only prefer old-growth and mature forestland, but they use a great deal of it. Studies of the home ranges of owl pairs in various provinces showed that owls use areas as small as about 1,000 acres and as large as 27,000 acres. Median home ranges of 3,000 to 9,000 acres were typical. A further factor that accounts for the large amount of habitat needed to support owl populations is the need for numbers of owl pairs and individual owls to occupy a contiguous habitat area within which they can interact. The long-term survival of a species depends not just upon the survival of individuals but also upon successful mating, raising of young, and dispersal of new adults. For owls, this requires relatively large contiguous areas of habitat within which individual owls can interact.

The need to preserve large areas of old-growth and mature forestland brings owl conservation into direct conflict with timber harvesting. For decades, old-growth timber has been the primary source of logs for the timber and wood products industries of the Pacific Northwest. Stands of large trees provide a larger volume of high quality wood at lower cost than do younger stands.

Unfortunately, many of the forest management practices that have been used to increase the returns from timber harvesting and growing have been detrimental to owl habitat. Not only does the practice of clear-cutting remove old-growth trees from the land, but the regenerated forests grown on cleared land are often even-aged, single-species stands with little habitat value for owls. The patchwork of regenerated clear-cuts distributed across the landscape after decades of timber harvesting breaks up the continuity of the habitat available for owls. Although owls are often found in young or mature stands, their success in mating and raising young appears to be reduced by habitat fragmentation. Furthermore, the harvest of old-growth allows cleared land to be used to grow new trees. Younger trees grow more rapidly than old trees. From the standpoint of long-term timber supply, the more rapid growth in younger stands helps to support higher levels of sustainable timber harvest.

The sustainable yield concept that underlies most modern forest management relies in part on the fact that regenerated forests grow more rapidly than the old-growth they replace. Simply stated, sustainable yield harvesting of timber limits the removal of timber to the rate at which timber can be regrown within the management area. The growth in regenerated forests is considered in setting the rate of cutting of old-growth.

There has been considerable debate about whether the past level of federal timber harvest in the Pacific Northwest is, in fact, sustainable. This is a complex issue and its resolution is beyond the scope of the Recovery Team's responsibility. The level of future timber harvest that would occur if there were no owl conservation is the baseline for the analysis of the economic effects of the recovery plan. If harvest levels in coming decades turn out to be lower than they were during the 1980s or are lower than indicated by current forest plans, then timber industry employment and timber revenues also will be lower, even without owl conservation. The economic losses resulting from a lower baseline harvest should not be attributed to owl conservation measures.

However, it is important to recognize that economic losses resulting from other declines in timber harvesting will be exacerbated by the costs of protecting owl habitat. Removal of forestlands from the timber base to protect owl habitat may have spillover effects on the rate of timber sales in federal forests. Furthermore, timber dependent communities may be less able to adapt to the effects of owl conservation because of the effects of other declines in timber harvest. For the purposes of this analysis, however, the costs attributable to the need to protect owl habitat were treated as independent from costs associated with reductions in the baseline harvest level.

The problem posed by the owl's need for extensive areas of commercially valuable old-growth and mature forest is evident in a few statistics. Although the variety of definitions of old-growth makes assessment of trends somewhat confusing, it is clear that the trend has been sharply downward. For example, Booth estimated the amount of prelogging old-growth 200 years or older. Prior to the start of logging, an estimated 19.8 million acres of old-growth were present in western portions of Oregon and Washington (Booth 1991). By the early 1980s, more that 80 percent of this original old-growth had disappeared, with federal lands containing most of the residual old-growth (Booth 1991). Haynes (1986) estimated that about 3.5 million acres of old-growth forests (200 years or older) remained on nonwilderness lands. Another source, the ISC report, cited an estimate that 17.5 million acres of suitable habitat were available for owls in 1800 (Thomas et al. 1990). By the 1990s, only about 7.1 million acres were available. The Forest Service recently produced estimates of old-growth by gathering information from a wide range of forestland owners. Reports from various owners use different definitions of old-growth. This survey estimates that there currently are 10.4 million acres of old-growth, of which 8.8 million acres are on federal land, including wilderness areas and national parks.

In the 1980s, old-growth harvest on federal lands proceeded at about 3 to 4 billion board feet per year, mostly by clear-cutting. Although inventories of spotted owl habitat are not available to measure its decline during this period, habitat would have continued to decline steeply because of this rate of harvest.

On the economic side of the balance, old-growth harvests from federal lands were worth more than $1 billion per year, providing substantial revenue that was shared between the U.S. Treasury and the state and county governments. Direct employment in the timber and wood products industries that depend on the supply of logs from old-growth harvests of federal lands has provided jobs to about 30,000 people.

In general, the harvest of timber in the Pacific Northwest has occurred earlier and more rapidly on private forestlands than on public forestlands. Significant harvesting of timber in the national forests did not begin until after World War II. Several consequences of this pattern affect the preservation of owl habitat and its economic effects. First, because most of the private old-growth forestland has been harvested, most of the remaining forestland that provides the best owl habitat is on federal forests. Second, it was expected that the total timber harvest in the Northwest in the next few decades (while the regrowth on private lands matured) would be sustained by harvest from federal forests. Sustained yield or nondeclining flow concepts being used in setting the rate of timber sales from federal forests were applied to the substantial areas of old-growth timber in these forests. The removal of a substantial portion of this timber inventory from the timber resource base will reduce the federal harvest level during a period when private forests are not capable of sustaining a significant increase in harvest.

IV. Economic and Social Cost Information Considered in the Formation of the Recovery Plan

In addition to the economic principles discussed earlier, the Recovery Team considered several types of economic information. These included:

- The estimated costs of previous owl conservation proposals,
- Indicators of the dependency and sensitivity of local economies to timber harvest,
- Indicators of the effects of various elements of the recovery plan and other owl conservation proposals on timber harvest, revenues, and employment,
- Estimates of the costs and returns of various silvicultural practices.

The first two categories of information were used to provide a context that would facilitate the design of lower cost options for consideration. The third was used in the assessment of the various management actions the Recovery Team considered for inclusion in the recovery plan. Most of the evaluation criteria were intended to help the Recovery Team evaluate the likely contribution of various options toward recovery. Harvest and employment effects were included to show whether various options were substantially different in their costs. The Recovery Team also reviewed estimates of the costs and revenues from silvicultural practices that might be used to promote development of owl habitat.

The Recovery Team also considered information on the social costs of implementing owl conservation measures from several sociological studies.

When the Recovery Team completed formulation of the draft recovery plan, it prepared preliminary estimates of the economic costs of its implementation. These are described in section IV. Section IV also provides a discussion of the concepts and analytical methods used to estimate the indicators of employment and revenue effects.

A. Previously Estimated Economic Costs of Owl Conservation Proposals

The Recovery Team reviewed six major studies of the economic effects of owl conservation. This was done to gain a better understanding of the factors that contribute to the high cost of protecting the owl and to identify analytic methods, assumptions, and data that could be used in producing economic information about the recovery plan. These studies are summarized briefly.

1. *The Economic Consequences of Preserving Old-Growth Timber for Spotted Owls in Oregon and Washington.* Walter J. Mead et al., University of California, Santa Barbara. October 1990.

This study provided a comprehensive analysis of the economic effects of preserving the remaining old-growth forests of Oregon and Washington to provide habitat for the owl. In addition to the nearly 2 million acres of old-growth already set aside in preserves, such as national parks and wilderness areas, the proposal would protect from harvesting all other old-growth, estimated here to be more than 4 million acres. A harvest reduction of 2,257 million board feet on federal lands is estimated to be partially offset in early years by increased harvest from younger forests on private lands.

The estimated net cost of this proposal during the next 50 years is $24.5 billion (discounted to present value at 4 percent). Direct job losses are estimated to be as high as 18,000 jobs.

The Mead study provided estimates of the following economic effects:
• The value of foregone old-growth timber harvest,
• The value of foregone second-growth timber harvest that would have been grown on lands from which old-growth is cut,
• The loss in the value of capital equipment, primarily saw mills,
• The loss in the value of labor due to unemployment and reemployment at lower wages,
• The increased value of recreation in old-growth forests.

2. *Social and Economic Impacts of Spotted Owl Conservation Strategy*. John H. Beuter et al., for the American Forest Resource Alliance, 1990.

The Beuter study examined the economic, social, and cultural effects of the conservation strategy for the northern spotted owl prepared by the Interagency Scientific Committee (ISC) (Thomas et al. 1990). The ISC strategy established a network of habitat conservation areas (HCAs) encompassing about 5 million acres of forestland managed by the Forest Service and the BLM. Significant portions of the HCAs are not currently old-growth, but under the prohibition on timber harvest in HCAs, these portions would become owl habitat in future decades. Significant amounts of old-growth forests were not included in the HCAs, but were to be partly protected under a rule requiring 50 percent of each quarter-township of federal forest outside the HCAs to be left with trees averaging at least 11 inches in diameter and providing 40 percent canopy closure (the 50-11-40 rule).

The estimated annual timber harvest on federal lands in the Pacific Northwest during the 1991-2000 period would be reduced by 1.6 billion board feet. Oregon and Washington federal lands would experience an estimated reduction of 1.4 billion board feet per year.

The Beuter study estimates that the implementation of the ISC strategy on public land would cause direct job losses of 17,133 and total job losses of

40,321. Income losses are estimated to be $1.0 billion. In making these estimates, adjustments were made for job and income losses caused by other reductions in timber harvest plans and technological change.

The Beuter study provided estimates of the following economic effects:
• Changes in employment,
• Changes in income and gross state product,
• Tax effects,
• Effects on revenues to local governments from federal timber sales,
• Social and cultural effects on timber dependent communities.

3. *Economic Effects of Implementing a Conservation Strategy for the Northern Spotted Owl.* Tom Hamilton et al., Forest Service and BLM, May 1990.

This study was performed by the Forest Service and the BLM to asses the effects of implementing the ISC strategy. It estimated that federal timber sales would be reduced from the planned 1995 level of 4.4 billion board feet to 2.6 billion board feet, a reduction of 2.4 billion board feet. The reduction in total employment resulting from these restrictions was estimated to be 25,409 jobs. The value of the foregone timber harvest was estimated to be $392 million in 1995. An analysis of the potential market response estimated that timber prices would be about 30 percent higher in 1995 if the ISC strategy were implemented and the the private timber harvest would be 1.1 billion board feet greater. The higher prices and private harvest would partially offset the revenue and employment effects of the foregone federal timber sales, but could not be sustained because of inadequate private timber inventories.

4. *Three-State Impact of Spotted Owl Conservation and Other Timber Harvest Reductions.* Bruce R. Lippke et al., Center for International Trade in Forest Products, University of Washington, September 1990.

The Lippke study also estimated the impacts of implementing the ISC strategy. It estimated that federal timber harvests would be reduced by 1.7 billion board feet per year and that state and private harvests could be reduced by 1.0 billion board feet. The Lippke study estimated that the implementation of the ISC strategy on public land would cause direct job losses of 22,919 and total job losses of 48,130. Income losses are estimated to be $530 million per year if there is no reemployment. In making these estimates, adjustments were made for job and income losses caused by other reductions in timber harvest plans.

The Lippke study provided estimates of the following economic effects:
• Changes in employment,
• Changes in income,
• Tax effects,
• Effects on federal revenues from timber sales,
• Effects on revenues to local governments from federal timber sales,
• Capital asset losses suffered by mill owners and homeowners,
• Gains to other U.S. and foreign timber producers and,
• Social impacts in timber dependent communities.

5. *Conservation Plans for the Northern Spotted Owl and Other Forest Management Proposals in Oregon: Economic Implications of Changing Timber Availability.* Brian J. Greber et al., Oregon State University, July 1990.

This study estimated the effects of the ISC strategy on timber harvests, employment, wage and salary losses, and local government funding in Oregon. It estimated that the ISC strategy would reduce federal and state timber harvests in Oregon by 1.154 billion board feet per year in the 1990s, displacing 16,000 workers by 1995 and causing wage and salary losses of $682 million per year.

County receipts were estimated to decline by about $14 million or about 3.8 percent. These estimates reflect the assumption that there would be no change in private timber harvests.

The study also estimated the effects of private industry conservation efforts similar to the ISC policies and of private harvest increase in response to the higher timber prices that would result from federal conservation efforts. Private conservation was estimated to increase total job displacement to 42,100 jobs and income losses to $1.8 billion per year. An increase in private timber harvest, while not sustainable over the long run, would reduce job displacement in the 1990s to 4,700 jobs and the income losses to $199 million per year. These effects would be higher, however, in the next decade when private harvest would be lower than the sustainable level.

6. *Economic Analysis of Critical Habitat Designation Effects for the Northern Spotted Owl.* USDI January 1992.

The FWS prepared this analysis to accompany its January 1992 rulemaking to designate critical habitat for the northern spotted owl. It used estimates provided by the Forest Service and the BLM on the effects on federal timber harvest attributed to various efforts to protect owl habitat. This study provided estimates of timber harvest for the Forest Service and BLM forestlands according to the agencies' latest plans, under announced policies for implementation of the ISC strategy, and under the FWS determinations of whether timber sales would jeopardize the continued existence of the owl or adversely modify the designated critical habitat. The critical habitat includes most of the acreage in the ISC's HCAs plus about 1.7 million acres of federal forestland that was not included in HCAs.

The FWS study estimated that Forest Service and BLM implementation of the ISC strategy would reduce federal timber harvests in 1995 by 1.7 billion board feet per year. It estimated that the Forest Service and BLM implementation of the ISC strategy would cause total job losses of 27,705. The further protections provided by the FWS under the Endangered Species Act would reduce timber harvests by an additional 236 million board feet and total employment by an additional 3,311 jobs. The imposition of the prohibition on adverse modification of the critical habitat is estimated to cause additional reductions of 102 million board feet in the 1995 timber harvest and an additional loss of 1,420 jobs. The wage losses due to critical habitat designation were estimated to be $65 million in present value (discounted at 10 percent).

The FWS study also provided estimates of the following economic effects:
- Federal revenue from timber sales and the net loss to the U.S. Treasury,
- Changes in employment by county,
- Effects on revenues to counties from federal timber sales.

Although these studies analyzed somewhat different proposals using different methods and assumptions, they produced comparable estimates. Table H.1 summarizes selected estimates from the studies to facilitate comparison. It is clear that the costs of owl habitat protection are substantial at the national and regional levels. Nationally, the value of foregone timber harvest is the most significant cost. This cost is borne primarily by federal taxpayers. The counties that share federal timber receipts also are hurt by the loss of timber revenues. Employment and wage losses and asset losses also hit timber dependent communities hard.

Table H.1. Summary of previous studies of economic effects of northern spotted own conservation.

	Mead	Beuter	Lippke	Hamilton	FWS	
					ISC	ESA
Reductions in federal timber harvest *(millions of board feet)*	2,257[1]	1,800[2]	1,700[2]	2,400	1,682[3]	338[3]
Job loss						
Direct	7,225	17,133	22,919			
Total	18,000	40,321	48,130	25,409	27,705	4,731
Wage losses *(millions of dollars)*	1,049[4]	1,049[5]	4,600[6]			65[7]
Timber value losses (net) *(millions of dollars)*	23,371[4]			500[5]		

[1]In Washington and Oregon only, estimate for the first year reflects offset by increased private harvest.
[2]On public lands in all three states.
[3]FS and BLM lands in three states.
[4]Total present value over 50 years, discounted at 4 percent.
[5]Annually.
[6]Total present value.
[7]Present value discounted at 10 percent. Estimated only for the 1,690,000 acres of federal forestland that the critical habitat designation adds to the ISC's habitat conservation areas.

Sources: Mead et al. 1990, Beuter et al. 1990, Lippke et al. 1990, Hamilton et al. 1990, USDI 1992.
FWS = U.S. Fish and Wildlife Service
ISC = Interagency Scientific Committee
ESA = Endandered Species Act
FS = U.S. Forest Service
BLM = U.S. Bureau of Land Management

B. Potential Social Costs of Owl Conservation Measures

There is substantial literature on the social effects of economic changes in rural communities. Research on timber dependent communities has been used in several studies to assess the social effects of the timber harvest reductions that might result from owl conservation measures. This literature was reviewed and discussed by the Recovery Team. Existing sociologic studies do not provide a basis for quantitative estimates of the social effects that would result from implementation of the recovery plan or other owl conservation plans. Such studies do, however, allow an assessment that is useful in judging the types of social effects that are likely and in planning programs to mitigate such effects.

It appears likely that success of the recovery plan in the long run may depend substantially on how its social effects are handled. The support and cooperation of local communities has proven to be important in the success of many wildlife preservation programs. Experience with other large-scale wildlife conservation programs has shown that it is difficult to sustain a healthy and diverse ecosystem unless the human communities that depend on it are also healthy. It appears likely that, if people in timber dependent communities are to support efforts to protect the owl, substantial efforts will be needed to reduce the social costs they bear.

The work of Robert G. Lee of the University of Washington provides a good synthesis of studies of the social effects of owl conservation programs (Lee 1990 and 1991a). Louise Fortmann of the University of California, Berkeley, has studied similar effects in California (Fortmann et al. 1990). This work supports the use of employment and revenue estimates as indicators of economic and social effects. More importantly, it suggests that other factors may have an equally important bearing on the way people in timber dependent communities respond to the resulting changes in their lives.

Lee identified four factors that are likely to exacerbate the social effects of owl conservation: 1) an apparent shift from decentralized, participatory forestland management that is oriented toward community stability to centralized command and control regulation to protect owl habitat; 2) the perception that the federal government has reneged on its commitment to maintain a nondeclining even flow of timber from federal forests, a commitment on which many people based a lifelong commitment of their own resources; 3) a social structure that is less likely to adapt to permanently decreased employment and loss of personal and business assets in timber dependent communities than is assumed; 4) the potential emergence of conflict among different groups of people in which timber workers are stereotyped and stigmatized.

Lee's work suggests that these factors may create a situation that inhibits the adaptiveness of people in timber dependent communities and increases the undesirable social effects of reductions in federal timber harvest.

Research in timber dependent communities suggests that the shift from decentralized forest management to centralized species preservation policy causes increased opposition to owl conservation measures. As a result, implementation of owl conservation plans is likely to require greater use of enforcement measures and greater short-term exploitation of the forests may occur. Accelerated liquidation of private timberlands may offset economic losses for some in the short run, but also may have undesirable ecological effects and exacerbate the decline in timber harvests in coming decades.

The removal of forestland from the timber base to protect owl habitat will cause a permanent decrease in timber harvest levels. This is perceived by people in

timber dependent communities as a betrayal. Many people in these communities have committed their personal energies and financial resources in response to the government's assurance of a nondeclining flow of timber from federal forests. Many regarded this policy as a promise on the part of the government. The federal timber harvest was expected to play a particularly important role in the next decade or two because of the inadequacy of the timber inventory on private lands to sustain harvest levels during that period.

People in these communities have developed ways of adapting to the cyclical unemployment that results from changes in the demand for timber that have been induced by national economic cycles. These adaptations depend in part on the assurance that the timber supply would be adequate to support recovery as soon as the demand for timber rebounded. As Lee reported, these adaptations are not well suited for coping with permanent reductions in timber harvest levels, the resulting permanent reductions in timber industry employment and the resulting effects on peoples' income.

Sociological research in timber-dependent communities has shown that people developed shared values and behavior patterns that allowed them to cope with cyclical changes in timber demand. People share a commitment to hard work, individualism, and self-reliance. While these values often are regarded as the bedrock of American culture, they may inhibit the development of cohesiveness and adaptability needed to make the changes in careers and economic structure to respond to a permanent decline in timber harvests.

As Lee reported, loggers have relied on their reputation as skilled woods workers and their mobility to find work. A logger has been able to improve his economic security by developing a reputation as a "good worker." Loggers appear to have developed a sense of occupational community, a commitment to logging as a way of life that may inhibit adaptation to permanent reduction in timber employment through career change. Many mill workers are less mobile than loggers and tend to be dependent on a single mill. Small business owners have committed their life's savings to investment in their enterprises, knowing that they would have some hard times during down-cycles, but expecting that, over the long run, the timber supply would provide support for their businesses.

The controversy about protection of the owl appears to have elements of an emerging conflict between urban populations wanting increased protection of environmental resources and rural populations that have worked in extractive industries. According to Lee, people in timber dependent communities fear the dominance of the urban majority and feel manipulated by the apparent expectation that they will adapt to the change in the timber supply. Moreover, this conflict is exacerbated by the attempt to exclude wood products workers from the larger community of people regarded as deserving sympathy and fair treatment (Lee 1991c).

Sociologic research indicates that the social costs in timber dependent communities may be heightened by the stereotyping and stigmatizing methods that some groups advocating preservation of owl habitat have employed, particularly against loggers. From their studies of behavior in other communities, sociologists know that the resulting dehumanization can make victimization more likely and can cause maladaptive behavior among victims. The combination of economic stress and stigmatization can lead to increased loss of self-esteem, depression and passivity, drug and alcohol abuse, violence and family dysfunction. Sociologists regard such situations as life-threatening traumas that can cause maladaptive behavior patterns that can be transmitted through families for generations.

The contrast between the behavior described by sociologists and the behavior described by economists is worth noting. Economic models are based on the assumption that economic behavior is "rational." It is assumed, for example, that people are able to figure out and take the actions that would best improve their situations. Displaced workers, in this model, seek new training or move to new locations with better employment opportunities. Sociologic models, in contrast, recognize that people respond to some traumatic experiences in ways that prevent such economic adaptation. The resulting individual and community behavior patterns may inhibit people's recovery from traumatic changes in their situation.

Lee and other sociologists suggested that programs to protect the owl be accompanied by efforts to draw on the strengths of the people in timber dependent communities. Lee recommended, for example, that their entrepreneurial lifestyle and inventiveness be used to develop and implement silvicultural methods that would promote the growth of owl habitat and increase the value of timber that can be harvested.

Lee's work also points out the difficulties imposed on state and local governments by the combined effects of the unemployment and social effects resulting from owl habitat conservation and the decline in revenues received by counties from federal timber sales (Lee 1991b, and Bray and Lee 1991). Just as the demand for social services increases, the financial resources available to local governments will decrease because of the decline in federal timber receipts in which they share. Counties with a high dependency on federal timber and an above average proportion of protected owl habitat will suffer disproportionately.

Studies of this problem concluded that severely affected counties could have difficulty maintaining essential services and meeting the additional needs caused by economic dislocation. Many counties, particularly in Oregon, have received more than 50 percent of their revenues from federal timber receipts (Bray and Lee 1991). Federal receipts have been allocated primarily to schools and roads but support other programs as well. Reductions in funds from federal timber receipts would force cuts in services that are not mandated by law such as preventive health care, social services such as counseling and youth programs, parks and libraries. The reduction in such services is expected to heighten the social costs in communities hit by permanent reductions in employment opportunities and other effects of owl conservation policies.

C. Indicators of the Timber Dependency of Local Economies

One of the opportunities to reduce the economic and social costs of achieving recovery for the owl is to reduce the amount of habitat preservation in areas where it causes the highest cost. It is useful to identify those communities where people's incomes are most directly tied to timber harvests that might be affected by owl conservation. A closely related factor is the extent to which people will be able to find employment in other sectors because of the proximity to more diverse urban economies or local opportunities for economic diversification. Several of the studies reviewed by the Recovery Team included efforts to measure timber dependency. Instead of developing new indicators, the Recovery Team drew upon these efforts. They are summarized here.

The Beuter study included a substantial effort by Douglas C. Olson to assess the timber dependency of various multicounty regions in the three-state area.

Table H.2, taken from the Beuter study, summarizes the results of that effort, and shows that the highest dependency on timber occurs in southwest Washington and Southwest Oregon. West-central Oregon, the Olympic Peninsula, and western Oregon fall into a second tier of high dependency.

The FWS study developed job response coefficients for the 55 counties affected by owl conservation efforts. These coefficients reflect the flow of logs from harvest sites to mills and the direct and total employment that results in each county per million board feet of timber harvest. Table H.3 shows the job response coefficients for the 55 counties from the FWS study.

The FWS analysis also examined a variety of other economic indicators at the county level including unemployment, per capita income, percent of employment in the timber and wood products industries, the percent of federally owned land and dependence on federal timber harvest, and the effect of reductions in timber harvest on county revenues. These statistics are summarized in Table H.4.

Trends in economic development and population growth provide an important indicator of recent diversification in county economic structure. Counties that have experienced rapid population and income growth are participating in the general diversification of the economic structure in the Pacific Northwest, primarily through growth in service sectors and light industry. Data on changes in employment in timber and manufacturing assembled by the FWS for the 55 counties that may be affected by owl conservation also are included in Table H.4.

The FWS considered these factors in designing a process for deciding whether to exclude areas from the designation of critical habitat (USDI 1992). It used the effects on county budgets and timber based employment to identify 13 counties on which to focus exclusion decisions. These counties are:

Washington	**Oregon**	**California**
Chelan	Curry	Trinity
Clallam	Douglas	
Lewis	Hood River	
Skamania	Jackson	
	Josephine	
	Lane	
	Tillamook	
	Wasco	

The State of Washington has completed an evaluation of the potential jobs lost due to efforts to conserve the northern spotted owl. Using ISC recommendations as a benchmark and recent harvest levels as a base, 8,200 jobs in the forest products industry are considered to be at risk. These are distributed as follows:

Olympic Peninsula	1,161
Northwest Washington	1,849
Southwest Washington	1,964
Central Washington	855
Puget Sound	2,234
Eastern Washington	136

When indirect employment is considered in addition to the direct employment in the forest products industry, the total potential job loss in Washington is 20,800. These estimates reflect the actual harvest in recent years rather than timber sale plans and include indirect employment impacts for the entire state.

Table H.2. Economic dependency indexes for wood products and other selected industrial sectors, by economic area and region, 1985.

Economic Area/Region	Wood Products Primary	Wood Products Secondary	Other Manufacturing	Agriculture, Forestry and Fisheries	Services	Other	Total
	Dependency Indexes: Estimated Percent of Area's Economic Base in Each Sector						
Washington							
Puget Sound	7	2	31	16	14	30	100.0
Olympic Peninsula	40	5	0	9	19	27	100.0
Southwest	55	4	9	13	9	10	100.0
Western	13	0	40	7	13	27	100.0
Central	10	0	9	72	4	5	100.0
Oregon							
Northwest	23	3	10	44	8	12	100.0
West Central	45	6	2	21	13	13	100.0
Southwest	52	6	0	23	7	12	100.0
Western	40	5	4	22	6	23	100.0
Central	28	18	0	18	9	27	100.0
California							
North Coast	15	4	9	24	28	20	100.0
North Interior	17	5	0	17	23	38	100.0
Sacramento	2	3	6	44	21	24	100.0
Northern	5	3	3	22	27	40	100.0
3-State Owl Region	20	4	16	14	17	29	100.0

Dependency indexes in this table were determined exclusive of the government and household sectors. See Table A-2 in Olson (1990) for indexes determined with all sectors included. Also, see Table A-1 in Olson (1990) for more sector detail regarding indexes in this table.

Metropolitan areas are included in the economic areas as well as the regions in this table.

Source: Olson in Beuter et al. 1990.

Table H.3. Job response coefficients for affected counties.*

Washington County	Jobs/ mmbf	Oregon County	Jobs/ mmbf	California County	Jobs/ mmbf
Chelan	11.81	Benton	17.11	Colusa	8.01
Clallam	12.46	Clackamas	9.88	Del Norte	12.51
Clark	10.40	Clatsop	10.79	Glenn	8.0
Cowlitz	11.58	Columbia	10.79	Humboldt	14.29
Grays Harbor	12.46	Coos	14.47	Lake	12.51
Jefferson	10.30	Curry	13.92	Mendocino	12.51
King	12.00	Deschutes	15.58	Shasta	9.63
Kittitas	15.08	Douglas	13.87	Siskiyou	9.63
Klickitat	10.40	Hood River	8.51	Tehama	8.36
Lewis	10.40	Jackson	13.92	Trinity	10.03
Mason	10.72	Jefferson	14.17		
Okanogan	10.40	Josephine	13.92		
Pacific	10.30	Klamath	15.74		
Pierce	10.41	Lane	17.11		
Skagit	9.63	Lincoln	17.11		
Skamania	10.40	Linn	17.11		
Snohomish	10.41	Marion	14.02		
Thurston	10.72	Multnomah	11.05		
Wahkiakum	8.07	Polk	14.02		
Whatcom	9.63	Tillamook	9.46		
Yakima	15.08	Wasco	8.51		
		Washington	9.88		
		Yamhill	10.79		

*Includes direct, indirect, and induced jobs.
mmbf = million board feet
Source: USDI 1992.

Table H.4. Economic characteristics of counties affected by critical habitat designation.

State/County	(1990) Unem-ployment Rate	1989 Per Capita Income	1990 population per Square Mile	Timber and Wood Products Employ-ment (%)	Percent Employment Changes 1980-1989		Percent Federally Owned Land in County	Percent Dependence on Federal Timber	Percent* Reduction in County Revenue
					Change in Timber Jobs	Change in Manufacturing Jobs			
Washington									
Chelan	8.0	$17,335	18	1.3	-34	20	75	39.8	18
Clallam	7.0	$14,942	32	10.3	-33	12	46	60.6	8
Clark	4.9	$15,379	380	4.2	5	43	1	60.3	0
Cowlitz	6.9	$15,276	72	19.5	-36	7	3	5.1	1
Douglas	7.0	$15,539	14	0.0	-88	60	4		0
Grays Harbor	9.1	$14,772	33	17.8	-35	12	13	38.9	5
Jefferson	4.8	$15,378	11	1.3	-51	28	61	1.6	13
King	3.4	$22,125	708	1.1	4	30	24	24.8	0
Kittitas	7.1	$14,035	12	1.7	-6	8	29		10
Klickitat	11.4	$15,270	9	13.4	10	10	3	50.1	2
Lewis	7.9	$13,920	25	11.2	-22	12	30	55.9	17
Mason	6.1	$13,072	40	10.6	-21	18	27	6.3	6
Okanogan	9.9	$15,163	6	8.0	15	19	46	45.3	3
Pacific	8.1	$14,979	NA	NA	NA	NA	NA	1.6	NA
Pierce	4.8	$15,546	350	1.8	-10	30	31	46.1	0
Skagit	6.7	$16,163	46	3.1	-8	29	46	40.9	4
Skamania	16.0	$14,225	5	29.1	-21	-46	75	50.1	109
Snohomish	3.9	$17,832	222	2.2	-4	48	47	52.5	2
Thurston	5.0	$15,663	NA	1.9	NA	NA	NA	8.7	0
Wahkiakum	8.7	$15,715	NA	12.2	NA	NA	NA	NA	0
Whatcom	4.9	$15,457	60	3.1	61	35	61	39.0	3
Yakima	9.7	$14,494	44	2.3	10	22	19	NA	5
Oregon									
Benton	3.8	$16,687	104	4.0	127	16	5	57.5	16
Clackamas	3.5	$18,191	140	2.4	-14	40	43	63.9	7
Clatsop	6.4	$16,484	NA	4.7	NA	NA	NA	32.8	0
Columbia	7.4	$13,891	58	11.5	-2	15	0	6.8	0
Coos	8.9	$13,608	38	10.2	-36	-5	7	24.5	42
Curry	5.8	$13,799	17	10.1	-4	16	57	87.6	59
Deschutes	5.9	$15,836	25	8.7	47	41	75	10.5	3

State/County	(1990) Unemployment Rate	1989 Per Capita Income	1990 population per Square Mile	Timber and Wood Products Employment (%)	Percent Employment Changes 1980-1989: Change in Timber Jobs	Percent Employment Changes 1980-1989: Change in Manufacturing Jobs	Percent Federally Owned Land in County	Percent Dependence on Federal Timber	Percent* Reduction in County Revenue
Douglas	8.4	$13,353	19	19.6	8	9	29	81.6	62
Hood River	7.8	$15,438	32	5.7	7	18	63	52.7	18
Jackson	6.8	$14,046	53	9.0	18	22	26	76.1	45
Jefferson	6.3	$13,880	9	14.8	79	36	25	10.5	3
Josephine	8.0	$11,438	38	9.0	-3	20	33	94.2	49
Klamath	9.3	$13,540	10	16.0	-14	6	56	51.1	14
Lake	9.2	$14,443	1	14.7	NA	NA	70	82.1	0
Lane	5.9	$15,049	62	8.1	-11	14	47	60.4	30
Lincoln	5.9	$14,722	40	2.7	-39	14	29	57.5	30
Linn	7.8	$13,059	40	13.7	-18	9	33	41.2	30
Marion	5.4	$14,957	193	3.1	47	29	27	81.4	5
Multnomah	4.9	$18,308	1,355	1.3	-28	10	26	52.7	1
Polk	5.5	$13,582	67	3.8	-37	5	0	70.3	12
Tillamook	6.1	$13,360	20	4.8	-62	0	15	32.8	28
Wasco	7.8	$16,672	9	4.8	-9	-1	13	67.0	8
Washington	3.4	$18,596	430	1.1	29	35	1	18.9	0
Yamhill	5.3	$14,585	92	5.5	-6	25	6	58.5	6
California									
Del Norte	12.6	$12,139	24	6.5	-68	-14	72	13.5	15
Glenn	12.5	$16,185	19	0.5	-69	-9	24	75.5	3
Humboldt	7.7	$15,546	33	9.9	-18	6	20	1.8	5
Lake	9.4	$14,166	NA	0.2	NA	NA	NA	NA	2
Mendocino	8.1	$15,856	23	9.3	-4	10	14	14.9	1
Napa	4.7	$21,417	NA	NA	NA	NA	NA	NA	NA
Shasta	8.6	$15,567	39	4.0	1	29	40	41.7	2
Siskiyou	11.6	$14,300	7	9.7	-5	-2	62	71.7	8
Sonoma	4.4	$20,860	NA	NA	NA	NA	NA	5.7	NA
Tehama	10.7	$12,471	17	11.3	7	9	23	24.4	3
Trinity	12.2	$12,495	4	NA	4	-8	74	76.0	32

NA = data not available

*Revenue reductions estimated for effects of Forest Service and BLM implementation of the ISC strategy, the prohibition against federal actions that would jeopardize a threatened species and the designation of critical habitat.

Source: USDI 1992.

An analysis completed by the State of Washington identified the relative economic risk of 100 communities in areas affected by the reductions in federal timber harvest. Communities were designated as either high-risk, at risk, low-risk or uncertain on the basis of a number of criteria. The criteria included absolute and relative dependency on timber-based employment, dependency on federal timber supplies that are being reduced, and an assessment of the local industry.

The following factors were used to designate a community as high-risk:

- More than 20 percent of the population is employed in the wood products industry.
- Significant portions of the local wood products industry are dependent on national forest timber where harvest reductions are planned.

Table H.5 shows the results of this analysis.

Table H.5. High-risk communities in Washington.

East Skagit County/East Snohomish County:	Sedro Woolly Rockport Darrington Gold Bar Sultan
Western Clallam County:	Forks Beaver
East Lewis County:	Morton Glenoma Randle Packwood
Okanogan County:	Okanogan Omak Tonasket
Grays Harbor County:	Aberdeen Amanda Park Copalis Crossing Hoquiam Humptulips Montesano Pacific Beach Carlisle Neilton
Skamania County and Klickitat County:	Stevenson Carson Bingen White Salmon
Yakima County:	Naches

Source: Governor's Timber Team, Washington

The State of Oregon has performed a similar analysis to identify severely affected timber dependent communities that would receive services under the Oregon Economic Development Department's (OEDD) Timber Response Program. A community is considered to be severely affected if:

- It has had a 4 percent decline in employment in the timber industry since 1989 compared to the total 1990 workforce,
- Its annual average unemployment rate exceeds the state's annual average rate by more than 50 percent, or
- The OEDD director determines that the community has suffered or is likely to suffer a severe economic decline.

The communities shown on Table H.6 are affected by both timber supply and cyclical problems. While the spotted owl most directly affects western Oregon communities, eastern Oregon communities feel the pressure on log supply. Further, eastern Oregon communities primarily are affected by timber supply declines, particularly ponderosa pine, in the new federal forest plans. As a result, eastern Oregon comminities also are shown to be severely affected.

Table H.6 lists the Oregon communities declared to be severely affected as of November 19, 1991.

Table H.6. Severely affected communities and counties in Oregon (updated November 19, 1991*).

Communities

Astoria
Beavercreek
Blodgett
Brownsville
Camas Valley
Camp Sherman
Cascadia
Cave Junction
  Kerby
Chemult
Cheshire
Chiloquin
  Crater Lake
  Sprague River
Clatskanie
Coquille
Cottage Grove
  Saginaw
Crabtree
Culp Creek
Curtin
Days Creek
Deadwood
Dexter
Dillard
Elmira
Estacada
Foster
Garibaldi
Gilchrist
Glide
Gold Beach
Halfway
Harrisburg
Hines
Jefferson
  Marion
John Day
Lakeside
Lakeview
Lebanon
Lorane
Lostine
Lowell
  Fall Creek
Lyons
Mapleton
Marcola
Maupin
Medford
  Central Point
  White City
Merlin
Mill City
  Gates
Molalla
Monmouth
Monument
Myrtle Point
New Pine Creek
North Bend
North Powder
Noti
Oakridge
Philomath
Powell Butte
Prospect
Reedsport
Riddle
Ritter
Selma
Spray
Springfield
  Thurston
Sutherlin
Sweet Home
Swisshome
Tenmile
Tidewater
Tiller
Tygh Valley
Ukiah
Union
Vernonia
Walton
Warm Springs
Warrenton
Wilbur
Willamina
Williams
Yoncalla

Counties

Grant
Coos
Douglas
Lake
Harney
Klamath
Wheeler
Morrow
Umatilla

Source: Oregon Timber Response Program Status Report, November 1991.
*Affected by declines in log supply.

V. Preliminary Evaluation of the Economic Effects of Implementing the Spotted Owl Recovery Plan

A. Economic Effects Covered by Preliminary Estimates

The Recovery Team drew upon the studies summarized in Section IV, particularly the FWS analysis, to develop preliminary estimates of the economic costs of implementing the recovery plan. Estimates of the following indicators of economic costs were made:

• Reduction in federal timber sale volumes and revenues and the resulting effects on U.S. Treasury and county budgets.
• Reduction in employment levels.
• Reduction in wage and salary income due to unemployment and reemployment at lower wages.

Estimates were not made of other economic effects such as capital asset losses, recreation or the other benefits of forest preservation, and increased profits or harvest by private forestland owners. Quantitative estimates of social costs of implementing the recovery plan were not made.

These preliminary estimates were not intended to provide a complete basis for final decisions on the implementation of the draft recovery plan. During the public comment period, the Recovery Team will work with the Forest Service and the BLM to refine the estimates of effects of federal timber sales based on more site-specific data on potential timber yields. In addition, estimates will be prepared of economic effects not covered by the preliminary estimates.

This section summarizes the basic analytical concepts needed to estimate and properly account for the economic effects of reduced federal timber harvests. Next it summarizes the estimation methods and assumptions used for the preliminary estimates and presents the resulting estimates.

B. Analytical Concepts

This section provides an economic framework within which the various factors that affect the costs of achieving recovery can be related. The discussion is presented in qualitative, non-mathematical terms to facilitate a broader understanding and use of the concepts. The basic concepts are presented in a single period, comparative static analysis for the sake of simplicity. For a comprehensive analysis of long-term effects, the concepts would be extended to deal with many time periods. This would reflect the effects of timber growth and the concept that resource values realized sooner are worth more than the same value if realized later. It also would deal more explicitly with the dynamic processes through which local and regional economies adjust to the kind of structural economic change caused by policies restricting timber harvest. The following discussion takes a static approach to provide a more easily understandable analytical framework.

1. The Supply Curve.

The supply curve for a commodity is one of the fundamental concepts of economic analysis. It represents the rate of production for a commodity or

good that is achievable at various costs. For timber, the supply curve reflects the real costs that would be incurred in all the activities needed to grow trees, harvest timber, and bring logs to the mills to be sawn into lumber. Such costs include forest management, road construction, cutting and loading, and transportation. It also includes the cost of complying with regulations designed to reduce the environmental effects of these activities.

As is the general case with supply curves, the timber supply curve slopes upward as shown in Figure H.1. At any given time, there are numerous sites that could be harvested at various costs. When prices are higher, it is worthwhile incurring greater costs to harvest additional timber. The upward sloping supply curve reflects the economic diversity of the existing forestlands. It results from a mixture of stands of timber, some with relatively low costs per board foot, some with relatively high.

The supply curve can be derived from a table listing the annual amount of timber that could be harvested at each cost from each site in the inventory. The total amount that could be produced at each cost is the sum of the annual harvest at that cost from all the sites. The supply curve shows the annual production at each price which is the sum of the potential annual harvest at all costs less than or equal to the price. Table H.7 provides an example of this way of deriving a supply curve. Figure H.2 shows the supply curve derived from Table H.7.

A region's timber supply curve reflects the condition of its current inventory of standing timber. For example, Figure H.3 shows two supply curves, one that would yield very high levels of production over a broad range of timber prices and a second that yields relatively little production at low prices, moderate production at midrange prices and not much increase in production even at fairly high prices. The first would characterize production from the forestlands in a region that has a substantial inventory of mature standing timber, the second from a region with limited forestlands or forestlands where the lower cost timber already has been harvested.

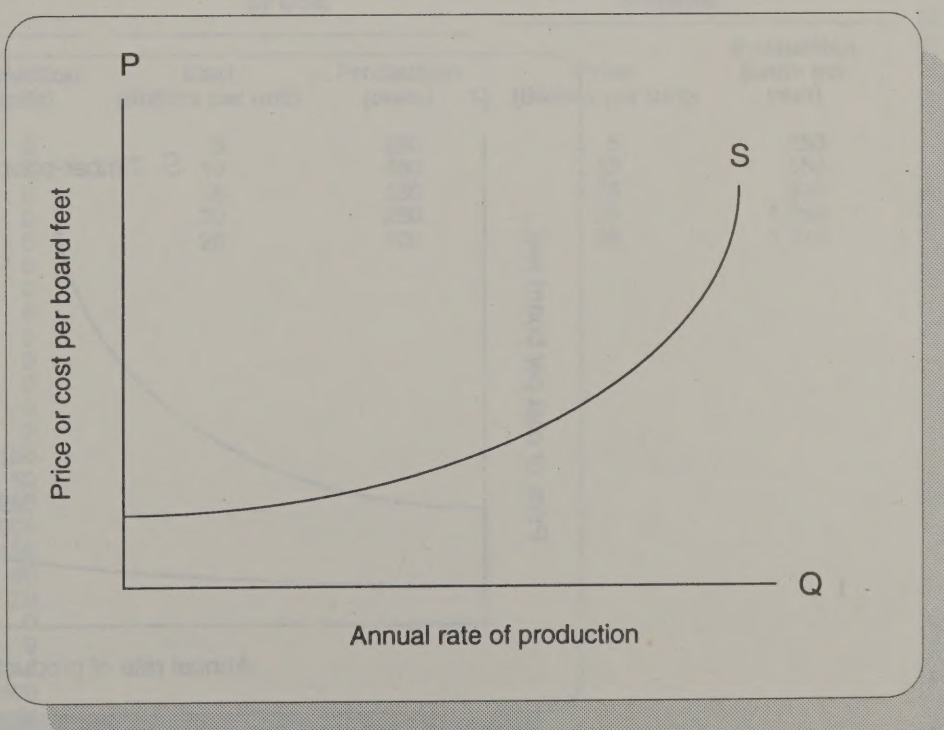

Figure H.1. *Timber supply curve.*

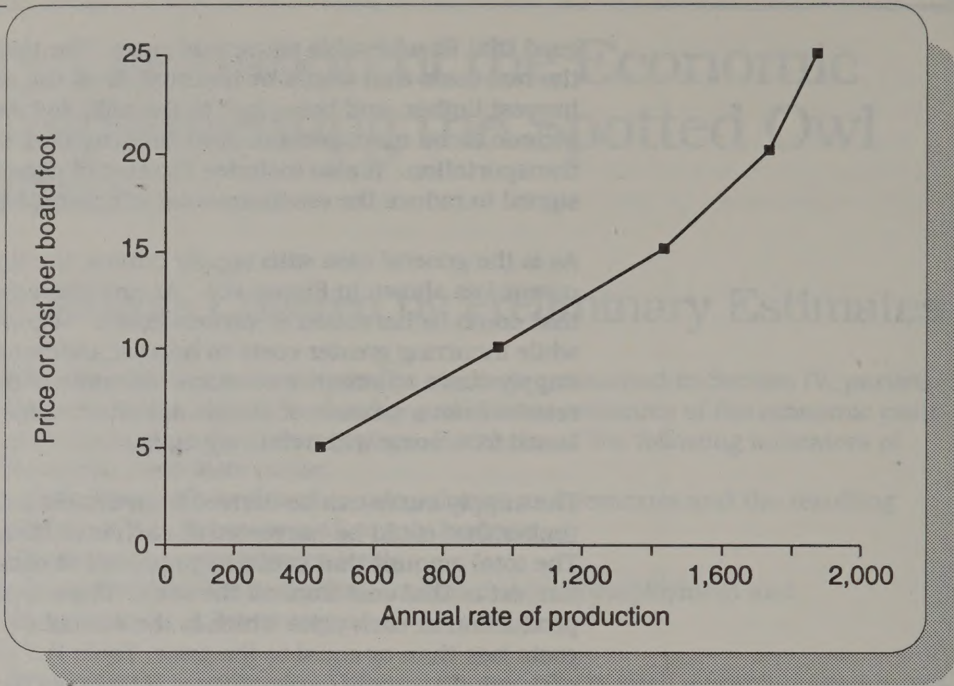

Figure H.2. Timber supply curve derived from Table 7.

The second supply curve also could represent the supply curve in a region in which lands with low cost timber were held off the market. Prohibiting timber harvests on sites with relatively low costs shifts the supply curve to the left for all higher costs. Table H.8 shows the supply schedule from Table H.7 recalculated to reflect the removal of sites 1 and 2. Figure H.4 shows the supply curve derived from Table H.8. As a comparison of Figures H.2 and H.4 shows, policies that remove harvestable timber from the timber resource base generally can be represented by a leftward shift in the supply curve from S_0 to S_1 as shown in Figure H.5. This is particularly true if low cost sources of timber are made unavailable for harvest.

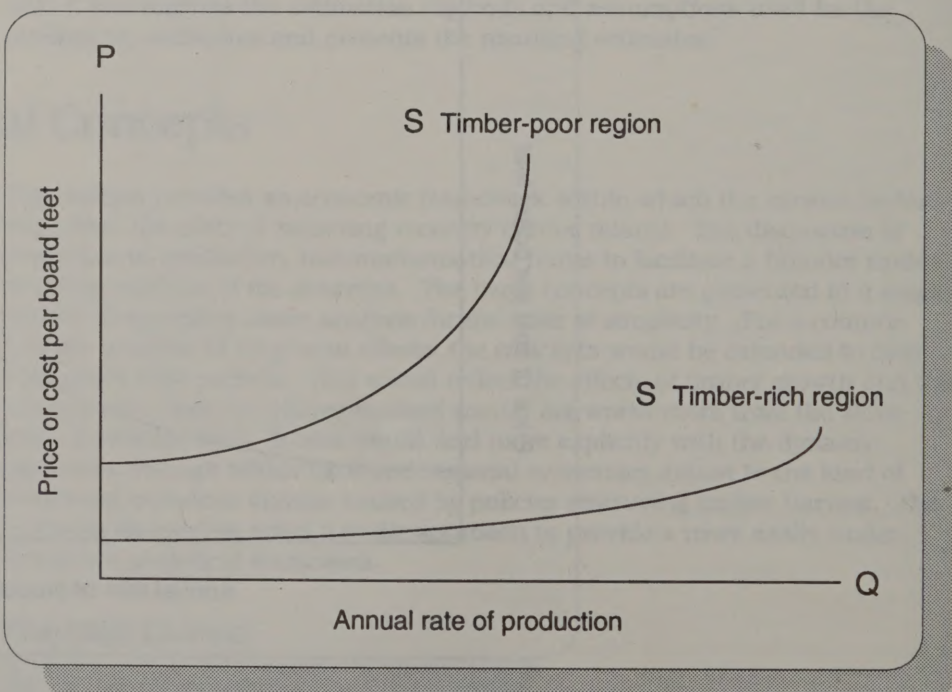

Figure H.3. Timber supply curves.

Table H.7. Derivation of timber supply curve.

	Potential Timber Production by Site and Cost		Potential Timber Production by Cost		Supply Schedule	
Site	Cost (dollars per unit)	Production (units)	Cost (dollars per unit)	Production (units)	Price (dollars per unit)	Production (units per year)
1	5	200	5	450	5	450
	10	110	10	510	10	960
	15	50	15	475	15	1,435
	20	0	20	300	20	1,735
	25	0	25	140	25	1,875
2	5	0				
	10	0				
	15	275				
	20	50				
	25	20				
3	5	0				
	10	0				
	15	0				
	20	100				
	25	50				
4	5	250				
	10	400				
	15	150				
	20	50				
	25	20				
5	5	0				
	10	0				
	15	0				
	20	100				
	25	50				

Table H.8. Effect of restricted timber availability on derivation of timber supply curve.

	Potential Timber Production by Site and Cost		Potential Timber Production by Cost		Supply Schedule	
Site	Cost (dollars per unit)	Production (units)	Cost (dollars per unit)	Production (units)	Price (dollars per unit)	Production (units per year)
1	5	0	5	250	5	250
	10	0	10	400	10	650
	15	0	15	150	15	800
	20	0	20	250	20	1,050
	25	0	25	120	25	1,170
2	5	0				
	10	0				
	15	0				
	20	0				
	25	0				
3	5	0				
	10	0				
	15	0				
	20	100				
	25	50				
4	5	250				
	10	400				
	15	150				
	20	50				
	25	20				
5	5	0				
	10	0				
	15	0				
	20	100				
	25	50				

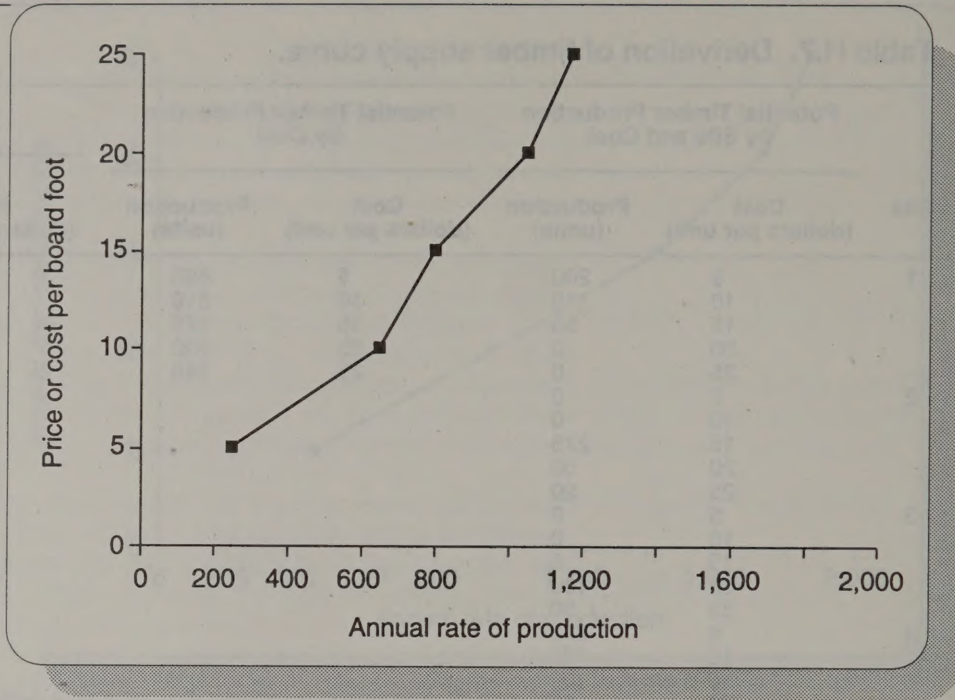

Figure H.4. Timber supply curve derived from Table H.8.

2. The Fundamental Economic Benefits of Timber Production.

The market for lumber is national. Lumber and wood products are shipped long distances and can be imported, primarily from Canada. Because of the available supply of lumber from timber grown in other regions and the flexibility in substitution of other materials for lumber, the level of timber production in the Pacific Northwest has only a small effect on lumber prices. If the rate of

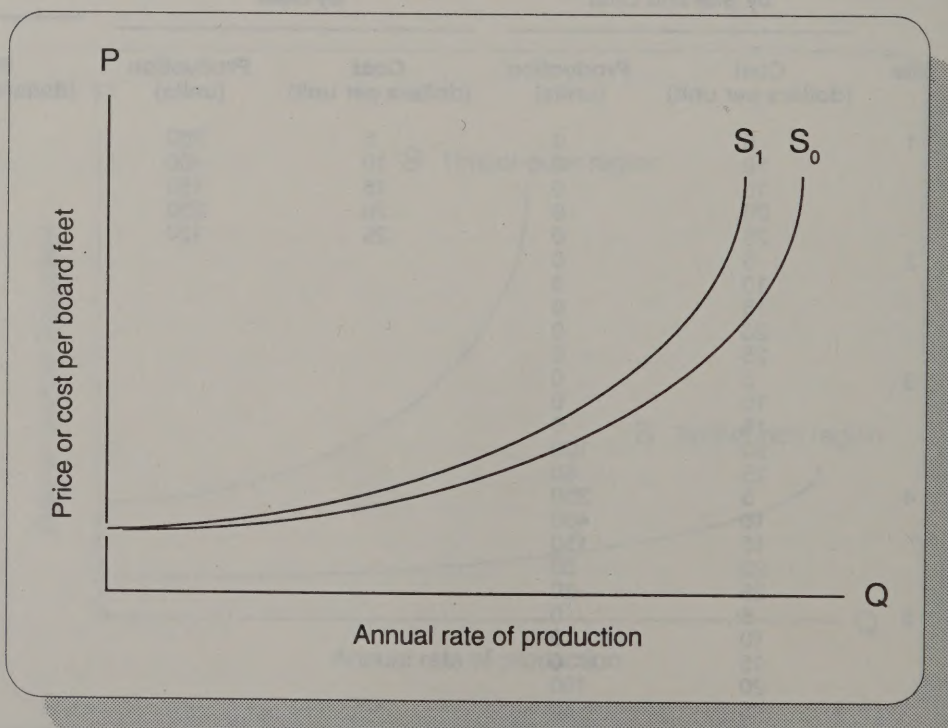

Figure H.5. Effect of removing low cost timber from timber supply curve.

timber harvesting in the Pacific Northwest does not much affect national lumber prices or consumption, it will not substantially affect the rate of consumption or the benefits that consumers experience from using lumber.

If lumber prices and consumption are not much affected by changes in Pacific Northwest timber production, what then is its benefit? Economists call the fundamental economic benefit from development of natural resources the economic rent. The economic rent from harvesting a stand of timber is the difference between the revenues from the sale of the timber harvested and the costs of all the various resources—labor, materials, energy, capital—used in harvesting and transporting them. As Figure H.6 shows, the price of timber, P_T, is determined by the intersection of the supply curve and the demand curve for timber. This intersection represents the market equilibrium between supply and demand.

In Figure H.6, the economic rent from the harvesting of Q_1 board feet per year sold at P_T, the price of timber, is the hatched area between the price line and the supply curve. The hatched area is what is left when the costs of production, which is represented by the area under the supply curve from the origin to Q_1, is subtracted from the rectangle that represents the production revenues, $P_T \times Q_1$.

Thus, a good measure of the direct economic benefit of producing timber is the gains the economy realizes by incurring less cost in harvesting and transporting logs than the price paid for the logs. These benefits are captured in a variety of forms: stumpage fees paid to landowners including the federal government and state governments, lumber company profits, federal income taxes, and state taxes. Stumpage prices are the best indicators of the economic benefit of the timber that is cut because competitive bidding for timber harvest contracts forces firms to bid away most of the difference between the value of the logs at the millgate and the costs of harvesting and transportation.

The timber supply curve in Figure H.6 shows the economic benefit that can be realized from harvesting various portions of the timber resources in a region's

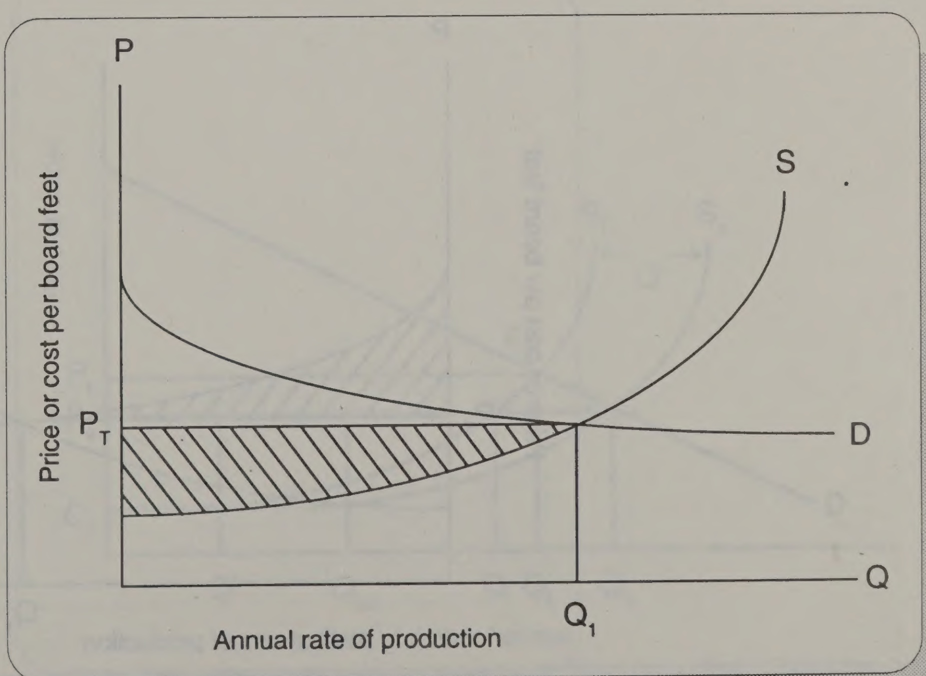

***Figure H.6.** Timber supply curve and economic rent.*

forestlands. The costs of production reflect technologies currently available and the current prices of the resources used to harvest and transport timber. Under ideal market conditions, the portion of the timber inventory that is brought into production would be the portion that yields economic rent at prevailing prices, thus contributing direct benefits to the economy. If timber prices are low, only the lower cost stands are brought into production. If timber prices are higher, then higher cost stands can be brought into production as well, increasing the total rate of production and the economic rent. The total economic rent realized from the timber produced is equal to the sum of the economic rent realized from each of the stands contributing to production.

Timber consumers, such as sawmills, plywood mills, and pulpmills, also benefit from the production of timber. The extent of such benefits depends on the prices at which they sell their products, the other costs they incur in processing wood, and the price they pay for timber.

Figure H.7 shows the same supply and demand curves as Figure H.6. The demand curve for timber shows the prices that timber buyers would be willing to pay for timber at different rates of timber consumption. The prices mills would pay depend on wood product prices and other mill operating costs. More efficient mills with lower operating costs can pay higher prices for timber and still make profits. Less efficient mills close when timber prices are high, reducing the rate of timber consumption. The substantial profits that can be made by most efficient mills during periods when timber prices are relatively low are represented by the difference between the highest prices on the demand curve and the prices set by the market when timber supplies are abundant. The hatched area in Figure H.7 represents the benefits to timber consumers, called the consumers' surplus by economists. In this case, it represents the sum of the profits made by mill operators at the timber price set by the market.

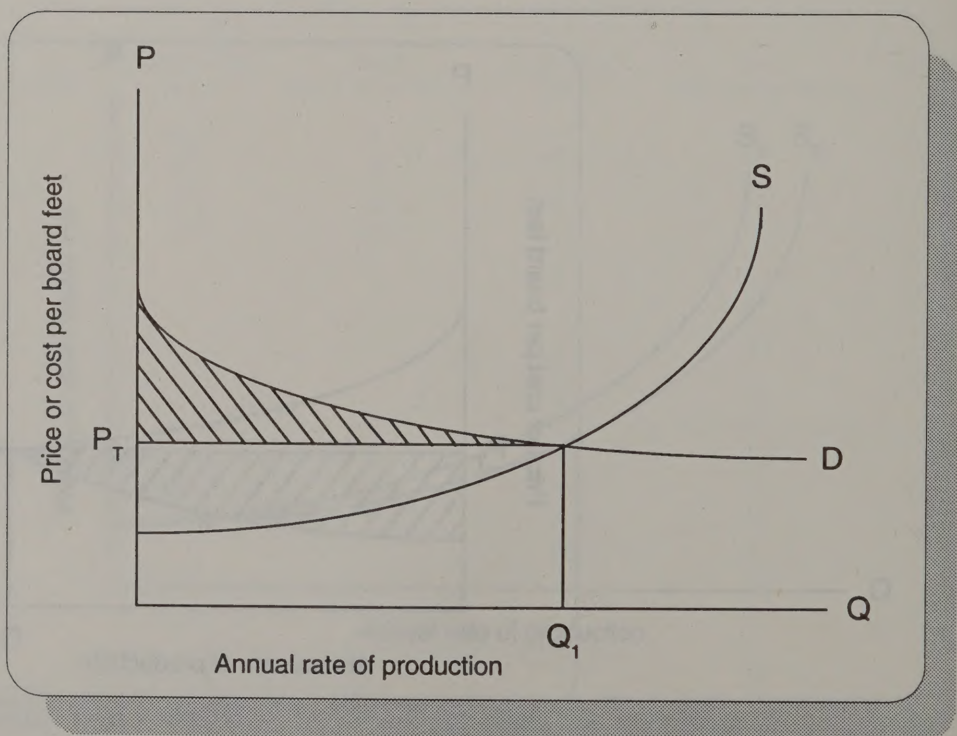

Figure H.7. Timber supply curve and consumers' surplus.

3. *Economic Effects of Owl Habitat Protection.*

The dedication of substantial areas of federal forestland to provide owl habitat will remove substantial amounts of land suitable for timber harvest from the federal timber base. What is the economic response and the effect on the various elements of the economy directly affected by this difference in the timber supply? In general, the following differences would be expected in future timber markets:

- The rate of federal timber harvest will be lower in future years than it would be without owl habitat protection.
- The rate of production from private lands will be somewhat higher.
- The price of timber will be somewhat higher.
- Federal revenues will be lower because of the foregone harvest, but higher on the remaining harvest because of the price increase.
- Private timber profits will be higher because of higher production and higher timber prices.
- Timber consumers, such as sawmills and plywood mills, will have lower profits because they must pay higher timber prices without receiving more for their lumber.

To estimate the extent of these effects, economists use the basic analytical concepts of supply and demand curves discussed earlier. Their application to the analysis of the effects of owl habitat protection is shown in Figure H.8. Without owl conservation measures, the total timber harvest would be Q_o, and the timber price would be P_o. The federal harvest, Q_{fed}, is shown as if it were the lowest cost source of supply, having cost approximately equal to C_o. Federal forests have most of the remaining old-growth timber that has the lowest cost per unit in the timber resource base. It is assumed that the rate of federal timber harvest would be lower by Q' because of the establishment of owl habitat conservation areas. In Figure H.8, the effect of the lower federal harvest, is shown by a leftward shift in the timber supply curve that results from deletion of the segment of the original supply curve from the origin to Q'.

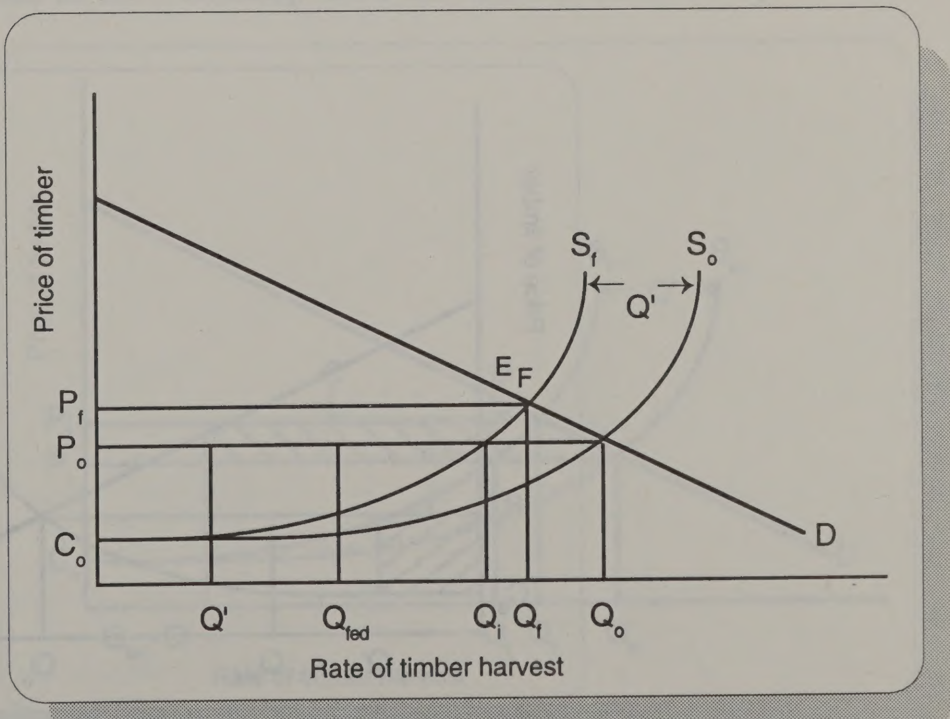

***Figure H.8.** Effects of removal of timberland on regional timber market.*

In Figure H.8, the equilibrium between the supply curve with owl habitat conservation, S_f, and the demand curve, D, is shown at E_f with the timber price, P_f, higher than P_o and timber harvest, Q_f. With owl conservation, the harvest rate, Q_f, is less than Q_o but greater than Q_i, the harvest rate equal to (Q_o - Q') that would occur if there were no increase in the private harvest rate in response to the restriction in federal harvest. These features of Figure H.8 can be used to estimate the direct economic effects of the removal of forestland from the timber base to protect the owl.

The basic concepts for analysis of the economic effects caused by owl habitat conservation are the economic rent realized from timber harvest and the consumers' surplus. The graphic representation of economic rent is shown in Figure H.6. The hatched area represents the sum of the profits landowners would realize from harvest on all of the forestlands contributing to the annual harvest. These lands range from those with low costs that yield high profits to others with costs nearly equal to the price which logs bring that yield almost no profit. The graphic representation of the consumers' surplus is shown in Figure H.7. The hatched area represents the sum of mill profits ranging from the high profits earned by the most efficient mills to nearly zero profits earned by economically marginal mills with high costs.

The federal government will not, of course, produce economic benefits or receive revenues for the portion of its timber that is on land reserved for owl habitat and must go unharvested. The economic benefit that would result from this harvest is equal to the difference between the value of the logs that would be produced and the cost of harvesting. This benefit is represented by Area A approximately equal to (P_o - C_o) x Q' in Figure H.9. The removal of federal forestland from the timber base to provide owl habitat causes economic losses equal to this unrealized benefit.

The economic benefits from the federal timber harvest that continues despite protection of owl habitat would be higher, however, because of the higher price of timber. The gain resulting from the higher timber price is shown in Figure

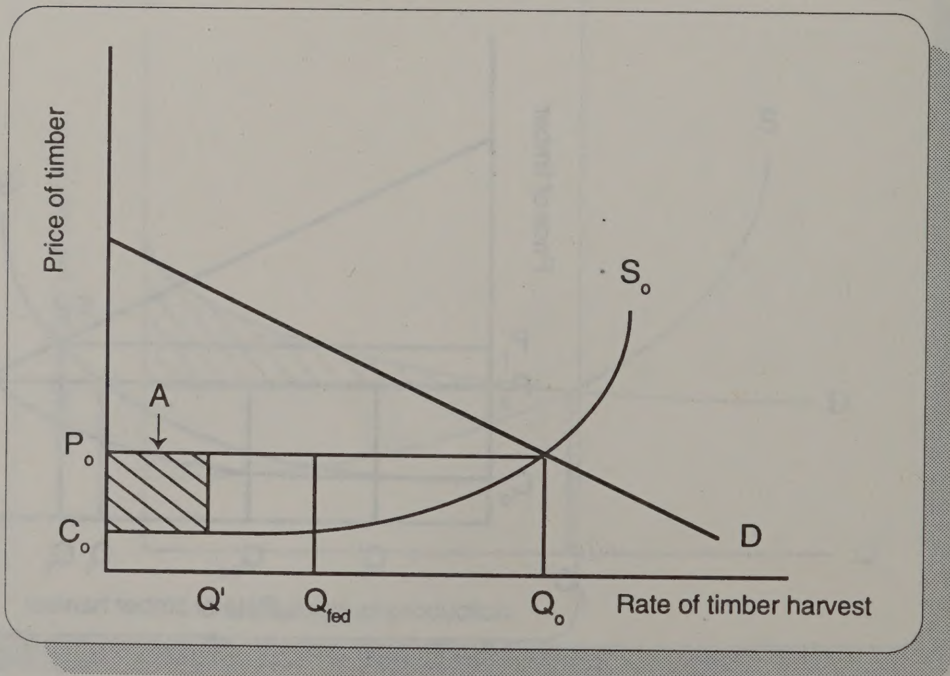

Figure H.9. Economic benefit foregone by reduction in federal timber harvest.

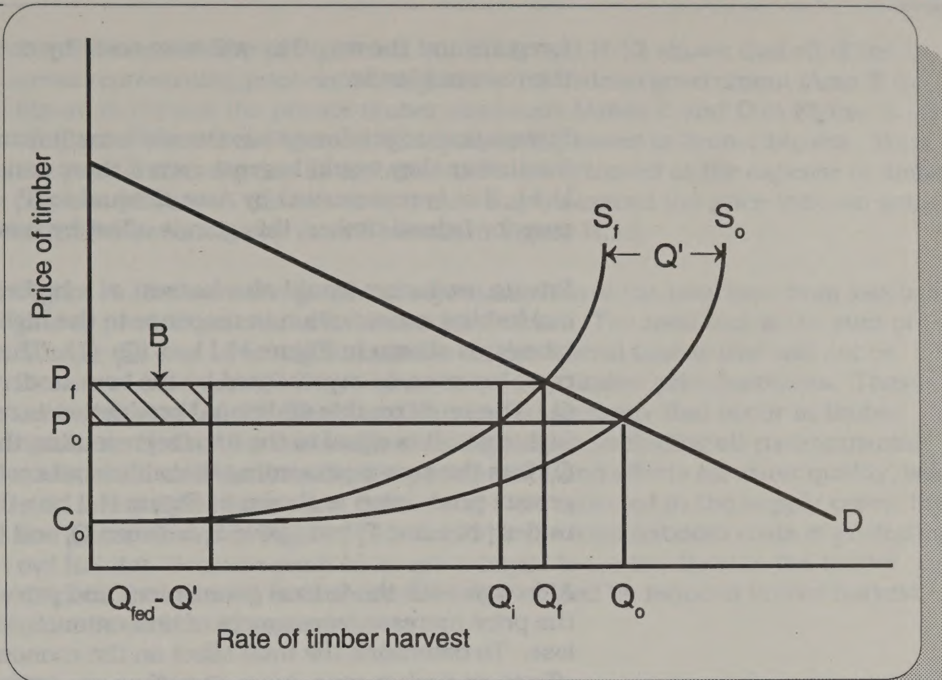

Figure H.10. *Price-induced gains in economic benefits from federal timber harvest.*

H.10 by Area B equal to $(P_f - P_o) \times (Q_{fed} - Q')$. As we shall see, these gains to the federal government are offset by losses to timber consumers.

To compute the effects of owl habitat conservation on the benefits and revenues from federal timber harvest, we must know the relationship between the analytical concepts shown in Figures H.9 and H.10, and (1) the way costs are incurred by federal agencies and the timber buyers and (2) the receipts from these sales. The BLM and Forest Service incur different costs and structure bids for timber differently. These differences will affect the receipts that are

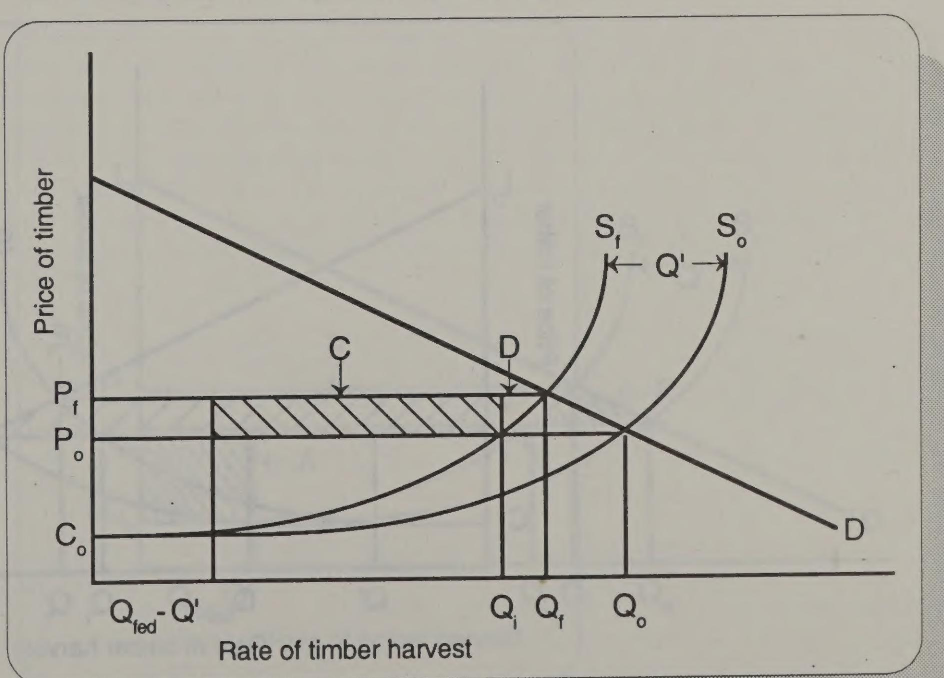

Figure H.11. *Price-induced gains in economic benefit from private timber harvest.*

foregone and the way they will save costs by not preparing for timber sales on the reserved lands.

Private timber producers also would benefit from receiving a higher price on the timber they would harvest even if there is no owl conservation. In Figure H.11, this is represented by Area C equal to $(P_f - P_o) \times (Q_1 - Q_{fed} + Q')$. As is the case for federal timber, this gain is offset by losses to timber consumers.

Private producers would also harvest at a higher rate in the case with federal owl habitat conservation in response to the higher price, P_f. The additional harvest is shown in Figure H.11 as $(Q_f - Q_i)$. This harvest is achieved at higher cost, however, as represented by the area under the supply curve, S_f from Q_i to Q_f. The profit on this additional production is relatively small because of its high cost. It is equal to the area representing the additional revenues, $P_f \times (Q_f - Q_i)$ less the area representing the additional costs. The profit on the additional private production is shown in Figure H.11 as the small triangular Area D under price line P_f but above S_f between Q_i and Q_f.

Although both the federal government and private timber owners benefit from the price increase, consumers of timber, such as sawmills and plywood mills, lose. To determine the total effect on the economy, we must estimate the effects on timber consumers as well as producers. Mills lose because the higher price of logs that results if timber harvest on federal lands is restricted by protection of owl habitat causes lower profits.

The graphic analysis of the effects on timber consumers is shown in Figure H.12. If there were no owl conservation, the timber buyers' benefits are represented by the roughly triangular area with corners at P_o, I_d and E_o. If owl conservation restricts timber supply, the timber buyers' benefits are represented by the roughly triangular area with corners at P_f, I_d and E_f. The losses experienced by timber buyers are represented by the difference between the two triangles, shown as Area E.

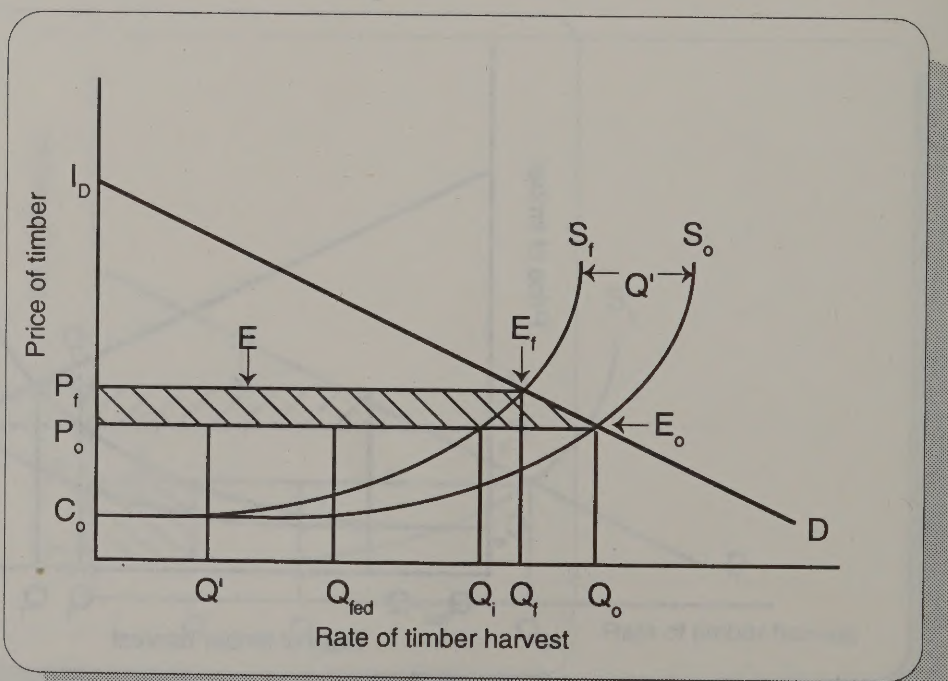

Figure H.12. Price-induced losses in benefits from milling.

Careful examination of Figures H.10, H.11, and H.12 shows that all of the areas representing price-induced gains to the federal government (Area B in Figure H.10) and the private timber producers (Areas C and D in Figure H.11) are part of Area E in Figure H.12 representing losses to timber buyers. Thus, the price-induced gains to timber owners are achieved at the expense of timber buyers. Moreover, the losses to timber buyers exceed the price-induced gains to timber producers by Area F shown in Figure H.13.

Figure H.13 shows the graphical representation of the total cost from loss in timber production due to habitat conservation. The total cost is the sum of Area A, the loss of economic benefits on the federal timber that will not be harvested, and Area F, the net loss caused by timber price increases. These costs reflect all of the effects on the national economy that occur in timber markets. If all of the costs of harvesting timber, including all environmental costs, such as lost recreational opportunities and effects on water quality, were paid for by firms harvesting timber and were reflected in the supply curve, then the losses shown in Figure H.13 would be the total national costs of protecting owl habitat. Because such costs are external to transactions in the timber market, the reduced environmental costs caused by reduced timber harvest must be estimated separately.

The economic effects of protecting owl habitat can be viewed from the regional as well as the national perspective. This requires an accounting of the effects on the regional share of the national economic benefits created by timber harvesting as well as for the effects on regional income generated by the purchase of labor, equipment, and services for the harvesting and processing of timber.

The region shares in the benefits from timber harvesting, shown in Figure H.6, in several ways. First, counties receive 25 percent to 50 percent of federal timber sales receipts. Second, firms that own forestland in the region earn profits on timber they harvest. State governments also receive revenue from timber harvest on state lands. The effects of owl habitat protection on these regional shares of the benefits from timber harvesting can be analyzed using the concepts shown in Figures H.9, H.10, and H.11.

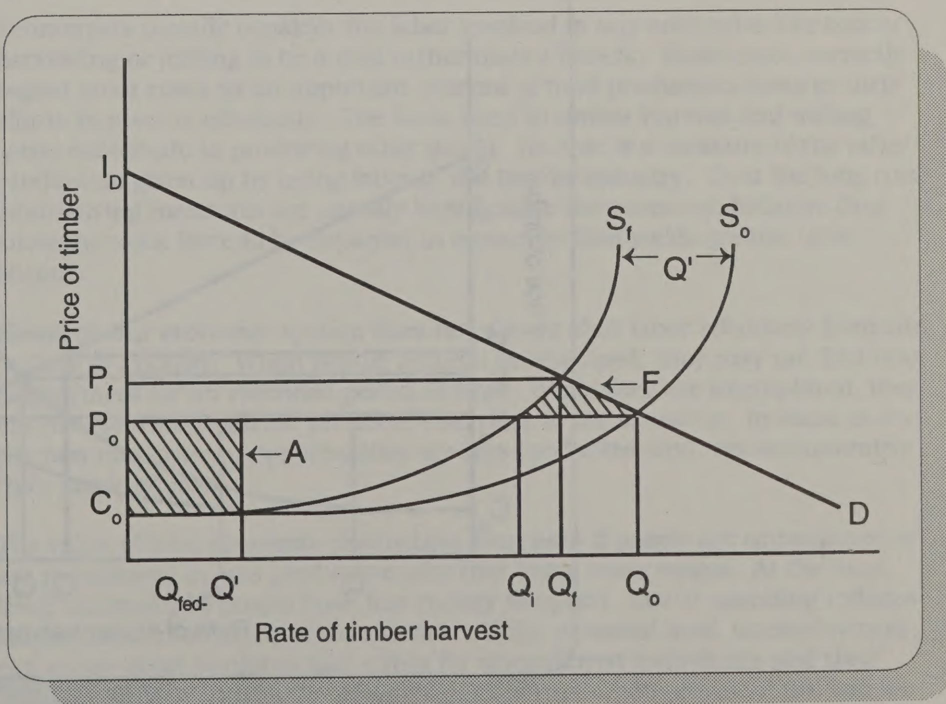

***Figure H.13.** Total economic losses from reduction in federal timber harvest.*

The income created by the purchase of labor, equipment, and materials used in harvesting and processing timber is also a part of the regional economy. Since the primary component of this income is wages and salaries, analysis of these effects is based upon concepts regarding the demand for labor in the timber industry and the relationship between the level of employment in the timber industry and the level of employment in related industries. The next section presents concepts that are useful for understanding the employment effects of protecting owl habitat.

The analytical concepts discussed earlier are static. They show differences between two future situations, one without protection of owl habitat, one with owl habitat protection. They do not show how the economy would change over time in response to the implementation of a new policy such as the recovery plan. A few observations can be made, however, about the dynamic response of the economy using the same concepts.

The response of the private timber industry to reductions in federal timber harvests in the Northwest is of particular interest. As shown in Figure H.14, the initial market response to the change in the timber supply is to drive timber prices up to P_i. Private timber owners will respond by increasing their rate of timber harvest to the extent that they can do so at a profit at the higher prices. This increased harvest will partially offset the reduction in the federal timber harvest and will drive the timber price down toward P_f. It appears, however, that the additional harvest from private forestlands will be limited in amount and duration because of the relatively small portion of that land with trees of harvestable, or nearly harvestable, age.

In general, timber harvesting in the present tends to reduce the potential harvest in future years. This effect of harvesting can be viewed as a tendency for the timber supply curve to shift toward the left over time, because the timber that is harvested tends to be the lower cost timber in the inventory.

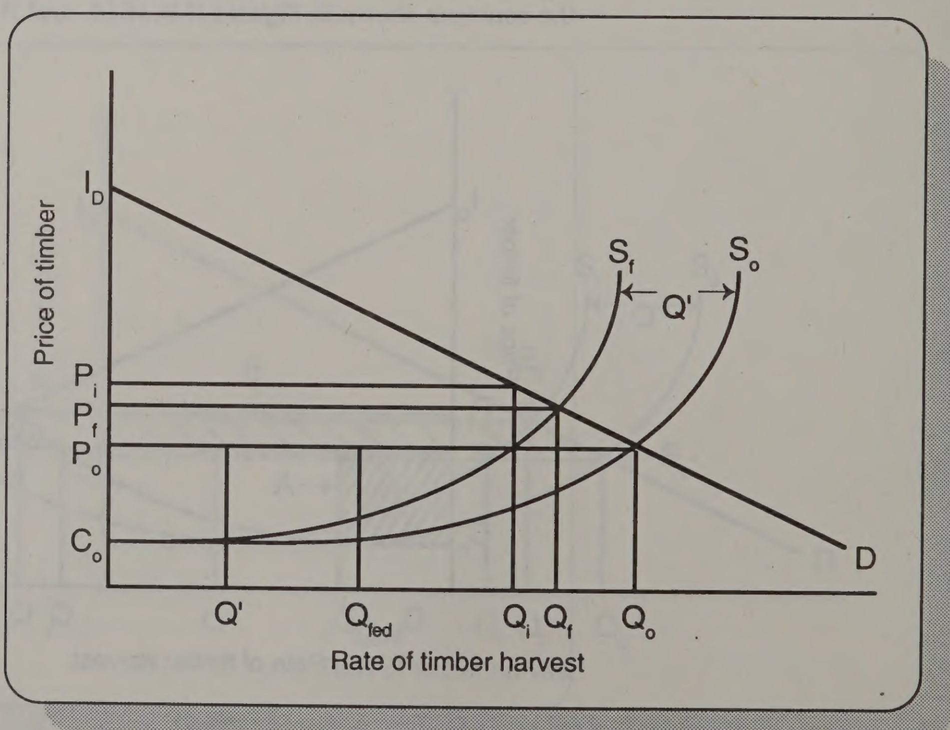

Figure H.14. Dynamic effects of removal of timberland on regional timber market.

The tendency of the supply curve to shift leftward over time due to harvesting is counteracted by the natural growth of trees in the inventory and by technological developments that reduce the costs of harvesting and transportation. The timber market tends to balance the overall rate of harvest with the rates of growth and technological progress.

In recent decades, federal timber harvest policy has provided assurance of future timber supplies, preventing the depletion of timber on private lands from causing expectations of higher future prices which are the market's signal to delay harvesting. As a result, private harvests have not slowed, creating a dip in the potential for harvest during the next decade or two.

The additional harvest from private forestlands also is likely to be limited by two factors that will tend to counteract the tendency for timber prices to remain higher. First, during the period of higher timber prices, some mills will be forced to close. The resulting decrease in mill capacity in the Northwest would appear in Figure H.14 as a downward shift in the demand curve. Second, the rate of timber harvest in other regions also would increase in response to the higher price. More lumber would be produced in other regions, putting further downward pressure on the demand for timber in the Northwest. The downward movement of the demand curve would tend to put downward pressure on timber prices, undercutting the increased harvest on private forestlands.

4. The Demand for Labor in the Timber Industry.

Reduced employment is an important effect of owl conservation measures, particularly at the personal and local levels. Because people lose their jobs and income, employment reductions are regarded as undesirable impacts. While such effects are bad at the personal and local level in the short run, paradoxically they are much less damaging over the long run at the regional and national level. To assess employment effects, it is useful to understand how labor markets operate to put people to work in ways that achieve greater total output and how timber availability affects employment.

Economists usually consider the labor involved in any enterprise like timber harvesting or milling to be a cost rather than a benefit. Businesses correctly regard labor costs as an important element of total production costs in their efforts to operate efficiently. The labor used in timber harvest and milling could contribute to producing other goods. Its cost is a measure of the other production given up by using labor in the timber industry. Over the long run, labor-saving measures are usually beneficial to the economy, because they allow the work force to be deployed in a manner that yields greater total output.

However, our economic system does not always shift labor effectively from one activity to another. When people become unemployed, they may not find new employment for an extended period of time. While they are unemployed, they are not contributing their productive services to the economy. In some cases, the new employment opportunities are less productive and less remunerative than previous jobs.

The value of total economic production decreases if people are unemployed or are reemployed in less productive jobs that bring lower wages. At the local level, unemployed people have less money to spend. Lower spending reduces employment in a variety of businesses. At the personal level, unemployment can cause great hardship and stress for unemployed individuals and their families. Extended periods of higher than normal unemployment are bad for the unemployed individuals and the economy as a whole.

Two concepts are useful for understanding the employment effects of owl conservation measures. One is the relationship among the various factors that affect the decisions of businesses with employment directly related to timber harvest, such as sawmills. The key factors of interest are the supply of timber and labor and the demand for timber. The second is the relationship between direct employment in timber cutting and milling and employment in related industries and in the economy as a whole.

Figure H.15 shows the factors that affect a sawmill's management decisions. The mill manager determines the rate of lumber production, the rate of timber purchases, and the amount of labor and other inputs it needs for that rate of production. These decisions are affected by the price of lumber, the price of timber, and the prices of labor and other inputs. The demand for workers in the timber industry results from the decisions of many mills and other businesses involved in the harvesting, transportation, and processing of timber.

The price of timber provides the connection between the availability of timber as represented by the timber supply curve and the rate of production and levels of employment in timber businesses. As shown in Figure H.5, the price of timber is represented by the intersection between the demand curve for timber and the supply curve.

The demand curve for timber shows the rate of timber consumption at each timber price. The demand for timber is derived from the demand for lumber. If there are many firms producing lumber, none can affect lumber prices. Each sawmill must sell its lumber at the market price. At a given lumber price, each sawmill's profits and production rate depend on the firm's costs. The price of timber is an important factor in the total costs of producing lumber. When timber prices increase, profits and the rate of production decrease.

Some firms are efficient enough to be able to absorb an increase in the price of timber and continue operating, though at lower output. Firms that were marginally profitable before an increase in timber prices will be forced to close. Thus when the price of timber in a region is higher, the total output of lumber will be lower.

To minimize costs, a firm would normally adjust its mix of inputs whenever an input price changed significantly. Often, increased use of some inputs can offset the reduction in use of an input whose price has increased. In sawmill operations, however, there is little flexibility to alter the amount of timber needed to make a board foot of lumber, at least in the short run (the period during which capital equipment cannot be changed). Therefore, to simplify the discussion, it is reasonable to assume that for each rate of lumber production there is a corresponding rate of timber purchases by the mill. Furthermore, for each rate of lumber production, there is a profit maximizing employment level. Thus, direct employment in the timber and wood products industries is higher when timber prices are lower. If restrictions in the availability of timber for harvest shift the supply curve to the left as in Figure H.5, timber prices will be higher. As a result, lumber output and direct employment will be lower.

The level of output in a region's timber industry also affects employment outside of that industry. Timber businesses buy goods and services from a variety of firms in other sectors of the economy, from equipment manufacturing to accounting. At lower levels of output, the timber industry uses less of these goods and services. Firms in other sectors must reduce their levels of output to avoid producing goods that cannot be sold. Workers are laid off or new hiring is deferred when such reductions occur. Thus changes in output in the timber and lumber industries induce changes in employment in other sectors. In addition to the direct employment effects of a change in timber availability, there are induced employment effects in the related industries.

Further employment effects, called indirect effects, occur because of the changes in income levels that are caused by changes in employment. Indirect effects result from the reduced consumer spending that is caused when unemployment reduces the income people have to spend. The total employment effects of reducing timber availability include direct, induced, and indirect effects.

5. Effects on the Value of Capital Assets.

The two forms of asset most strongly affected by the reduction of timber harvest are sawmills and homes. Home asset losses result from the decline in income of many residents in a community. Losses in the value of housing cause a transfer of wealth that can seriously affect people's lives, but such losses do not represent a significant loss to the output of the national economy.

Losses in the value of real estate also cause a reduction in the tax base of local governments. When mills close because they cannot make a profit at the higher timber prices that will result from owl conservation, the mill equipment usually is scrapped. Capital equipment of this sort is valued for the profits it can yield. Once the profits disappear, the value of the capital becomes negligible. Although the resulting loss in mill asset values reflects a loss in economic output in the national economy, that loss is already accounted for by the reduction in timber consumers' surplus (that is, profits) discussed earlier. Thus, separate estimates of housing and mill asset losses are of interest primarily because of their effect on the local or regional economy but they should not be added to the estimates of the underlying losses in the components of income that cause them.

C. Estimating Economic Effects of Implementing the Recovery Plan

As noted earlier, the FWS, with assistance from the Forest Service and BLM, conducted an economic analysis of the critical habitat designation for the northern spotted owl (USDI 1992). As a part of this analysis it developed methods to estimate the loss of federal timber harvest from various measures to protect owl habitat. It developed methods for estimating the employment effects of the resulting harvest reductions in each of the affected counties. It also developed methods to estimate the net effect on the U.S. Treasury and on the timber revenues shared with the county governments. The analysis provided a comparison of the effects of the original forest plans, the implementation of the ISC strategy and the effect of Endangered Species Act protections of the owl, including the designated critical habitat. To provide comparable preliminary estimates for the draft recovery plan, the ISC strategy, and the critical habitat designation, it was decided that the same methods of analysis, with some adjustments appropriate to the recovery plan, would be applied to estimate the economic effects of implementing the recovery plan.

The methods used for making preliminary estimates of the effects of implementing the recovery plan are summarized here.

1. Estimating the Loss of Benefits from Federal Timber Harvest.

The estimation of the loss in the economic benefits from the federal timber harvest that will be foregone to provide owl habitat (Area A in Figure H.13) is straightforward. An estimate of the change in the annual harvest is multiplied

by an estimate of the price that would have been bid for the timber. The appropriate price to use in this computation is the price that would occur if the recovery plan is not implemented.

The Forest Service and BLM provided the FWS estimates of the reduction in federal timber available for sale that would result from their plans, from implementation of the ISC strategy, and from the proposed designation of critical habitat for the spotted owl. The FWS used these estimates to derive estimates of timber productivity factors (in board feet per acre) for the HCA acreage and the acreage proposed for inclusion in the critical habitat in each national forest and BLM district. These factors were used to estimate the reductions in timber harvest (assuming that annual timber harvests would be, on average, equal to the amount available for sale) that would result from the DCAs proposed in the recovery plan. Productivity factors were adjusted to reflect differences in the proportion of land suitable for timber included in the DCAs as compared to the proportion in the HCAs in each forest. In addition to establishing the DCAs, the draft recovery plan would impose restructions on timber harvest on federal lands outside the DCAs, an area called the matrix. The draft recovery plan guidelines for management of the matrix are quite similar to those of the ISC strategy. For purposes of making preliminary estimates of the effects of the draft recovery plan, it was assumed that it would have similar effects on timber harvest within the matrix, a reduction of about 0.7 billion board feet per year.

It is important to note that the estimated reductions in future timber harvest are based upon the assumptions underlying the baseline estimates of the harvest under the final plans. In general, factors that would tend to reduce the harvest under these plans also would tend to reduce the harvest under the draft recovery plan, reducing estimated harvest levels for both the baseline and the draft recovery plan. The estimated annual timber harvests for the final plans, the current owl management regime (Forest Service and BLM implementation of the ISC strategy), and the effect of the Endangered Species Act including the designation of critical habitat, and the recovery plan are in Table H.9. To provide better estimates of the timber harvests under the recovery plan, the Forest Service and BLM will be asked during the public comment period to estimate the annual timber harvest levels under the recovery plan using the best site-specific information on timber yields available.

The estimated loss due to the timber harvest foregone in the DCAs is $470 million per year. This estimate is based on the reduction in timber harvest caused by withdrawal of the land in the DCAs and on estimates of 1995 timber prices developed by the Forest Service using the Timber Assessment Market Model (TAMM) for conditions expected under the final plans (USDA 1991a).

2. Estimating Employment Effects.

Substantial effort has been made in recent years to develop techniques for estimating the employment effects of reductions in the rate of timber harvest. In its economic analysis of proposed critical habitat, the FWS, with assistance from the Forest Service, developed job response coefficients for use in estimating the employment effects of the designation of critical habitat for the owl. These coefficients were developed by the Forest Service using IMPLAN, an input-output model that simulates the transactions between various sectors of the economy. Adjustments were made during the development of these job coefficients to reflect the log flows among counties. Adjustments also were made in the coefficients to remove the effects of the large metropolitan areas from the county coefficients. This was done to produce estimates of job losses that would measure the impacts within the rural regions whose economies are most closely related to timber production. A more detailed description of the

Table H.9. Comparison of federal timber available for harvest, 1995, with conservation areas and matrix rules.

	(Billions of board feet)		
	Timber Harvest With Final Plans	Timber Harvest With Current Owl Management*	Timber Harvest With Recovery Plan** (DCAs & Matrix)
Washington Forest Service	0.72	0.26	0.25
Oregon Forest Service	1.81	1.05	1.02
Oregon BLM	1.19	0.68	0.67
Oregon Subtotal	3.00	1.72	1.69
California Forest Service	0.50[a]	0.21	0.21
California BLM	0.00	0.00	0.00
California Subtotal	0.50	0.21	0.21
Salvage and Silviculture***			0.13
Three States Total	4.22	2.20	2.28
Forest Service	3.02	1.52	1.57
BLM	1.19	0.68	0.72

[a]Projections. Final forest plans have not been released.
*Estimates based on U.S. Fish and Wildlife Service analysis of critical habitat.
Assumes 56 percent of planned harvest in matrix is prohibited by listing under the Endangered Species Act and an additional 24 percent is prohibited in critical habitat outside of habitat conservation areas.
**Estimates assume effects of recovery plan matrix guidelines will be the same as effects of current owl management outside of the ISC's habitat conservation areas plus Endangered Species Act.
BLM will provide more precise estimate of matrix effects during draft recovery plan comment period.
*** Effects of limited silviculture and salvage in DCAs.
DCAs = designated conservation areas
BLM = USDI Bureau of Land Management

use of the IMPLAN model and these adjustments are provided in the FWS report (USDI 1992). The resulting job coefficients generally fall in the middle of the range of other multipliers that have been used for estimating employment effects of changes in timber harvest. They are generally consistent with the results of the review of a number of such studies by Stevens (1991).

The FWS used these job response coefficients to estimate the employment levels that would result from the timber harvests under the forest plans, the BLM and Forest Service implementation of the ISC strategy, and the Endangered Species Act, including designation of critical habitat. To provide a consistent analysis of the recovery plan, the same methods of analysis were applied to estimate its employment effects. Table H.3 shows the job coefficients used in this estimation. Table H.10 summarizes the estimated employment effects for various owl conservation plans. Table H.11 shows the employment effects of the draft recovery plan DCAs by county. It should be noted that those estimates do not reflect all of the employment effects within the three states because large urban areas have been removed in developing the county job coefficients (see USDI 1992).

Table H.10. Comparison of timber employment levels, 1995, related to federal timber harvest (with conservation areas and matrix).

	Timber Harvest With Final Plans	Timber Harvest With Current Owl Management*	Timber Harvest With Recovery Plan** (DCAs & Matrix)
Washington Forest Service	10,342	3,814	3,541
Oregon Forest Service	29,754	17,478	17,075
Oregon BLM	18,546	9,233	9,137
Oregon Subtotal	48,300	26,711	26,212
California Forest Service	7,728[a]	3,434	3,478
California BLM	25	0	0
California Subtotal	7,753	3,434	3,478
Salvage and Silviculture***			1,770
Three States Total	66,395	33,959	35,001
Forest Service	47,824	24,726	25,377
BLM	18,571	9,233	9,624

[a]Projections. Final forest plans have not been released.
*Estimates based on U.S. Fish and Wildlife Service analysis of critical habitat.
Assumes 56 percent of planned harvest in matrix is prohibited by listing under the Endangered Species Act and an additional 24 percent is prohibited in critical habitat outside of habitat conservation areas.
**Estimates assume effects of recovery plan matrix guidelines will be the same as effects of current owl management outside of the ISC's habitat conservation areas plus Endangered Species Act.
BLM will provide more precise estimate of matrix effects during draft recovery plan comment period.
*** Effects of limited silviculture and salvage in DCAs.
DCAs = designated conservation areas
BLM = USDI Bureau of Land Management

3. *Estimating Wage Losses.*

Protection of owl habitat causes wage losses because reductions in the level of employment in the timber industry cause layoffs. People who lose their jobs are unemployed for a period, during which they earn no income, and then at least some are reemployed, often at a lower wage. Some displaced workers gain reemployment within the timber industry, displacing other workers. To estimate the wage losses due to implementation of the recovery plan, it is necessary to estimate the number of workers that would be displaced each year, the period during which they would be unemployed, and the wage level at which they would be reemployed.

Wage losses were estimated for the draft recovery plan and for other owl habitat protection plans using the same methods used by the FWS in its analysis of the critical habitat designation. These estimates were based on the employment levels estimated for the annual harvest levels for the various plans. To estimate the period of unemployment, the FWS assumed that displaced workers will be reemployed over two years with 92 percent reemployed by the end of the first year after displacement and 8 percent at the end

Table H.11. State and county timber industry employment effects of withdrawing designated conservation areas (DCAs) from the timber base.

State/County	Timber and Wood Products 1989 Employment**	1995 Employment Losses Due to DCAs: Total Jobs	1995 Employment Losses Due to DCAs: Direct Jobs	1995 Direct Jobs Lost as Percent of 1989 Timber and Wood Products Employment
Washington				
Chelan	360	336	201	56.
Clallam	2,356	700	388	16.48
Clark	5,171	14	8	*0.16
Cowlitz	7,060	43	28	*0.39
Grays Harbor	4,262	354	196	5.
Jefferson	114	0	NA	*0.
King	9,049	45	23	*0.
Kittitas	194	64	38	20.
Klickitat	931	18	11	1.
Lewis	2,626	1,233	746	28.
Mason	1,456	134	78	5.
Okanogan	1,286	129	87	7.
Pierce	4,268	261	163	4.
Skagit	1,177	42	27	2.
Skamania	535	152	92	17.
Snohomish	4,959	683	426	9.
Thurston	1,481	0		*0.
Whatcom	1,981	73	47	2.
Yakima	2,097	0		*0.
Washington Total	**51,363**	**4,281**	**2,559**	**5.**
Oregon				
Benton	1,496	21	11	1.
Clackamas	3,460	382	257	7.
Coos	2,547	209	121	5.
Curry	929	505	283	30.
Deschutes	3,428	40	25	1.
Douglas	8,228	3,982	2,676	33.
Hood River	532	177	120	23.
Jackson	6,071	1,204	675	11.
Jefferson	999	0	NA	*0.
Josephine	2,186	155	82	4.
Klamath	3,769	352	219	6.
Lane	11,314	2,967	1,616	14.
Lincoln	496	33	18	4.
Linn	5,557	751	409	7.
Marion	3,430	569	321	9.
Multnomah	3,974	55	33	1.
Polk	880	4	2	*0.
Tillamook	423	184	112	26.
Wasco	326	139	94	29.
Yamhill	1,621	0	NA	*0.
Oregon Total	**61,666**	**11,729**	**7,075**	**11.**
California				
Del Norte	478	NA	NA	*0.
Glenn	47	NA	NA	*0.
Humboldt	4,623	800	482	10.
Lake	38	NA	NA	*0.
Mendocino	3,142	68	43	1.
Shasta	2,240	69	22	1.
Siskiyou	1,618	584	187	12.
Tehama	1,774	NA	NA	*0.
Trinity	425	352	181	43.
California Total	**14,385**	**1,873**	**914**	**6.**
Three-state Total	**127,414**	**17,883**	**10,548**	**8.**

*Less than 1 percent.
**County timber and wood products employment generally has declined since 1989.
NA = data not available.

of the second year. The same assumptions were used for the preliminary estimates of wage losses due to the implementation of the draft recovery plan. The assumption that 92 percent of unemployed workers would be reemployed by the end of the first year was derived from general unemployment data (see Mead et al. 1990) and probably overstates the rate or reemployment of timber industry workers displaced by permanent restrictions in timber harvest imposed to protect owl habitat. The wage losses from implementation of the recovery plan were estimated to be $1.42 billion. Wage losses for the current regime (planned implementation of the ISC strategy, the effects of listing, and the critical habitat designation) were estimated to be $1.46 billion.

4. Estimating the Economic Effects of Silvicultural Practices.

The recovery plan provides for the use of silvicultural techniques in DCAs for the purpose of promoting more rapid development of forest characteristics favorable to the owl in stands that do not currently have the characteristics of suitable habitat. In general, younger stands would be thinned in a manner that promotes more rapid development of larger trees and other structural characteristics of suitable owl habitat. These techniques are described and evaluated in Appendix G.

The implementation of silvicultural practices in DCAs is one of the features of the recovery plan with potential to reduce the undesirable economic effects of protecting owl habitat, particularly during the first decade. The direct economic effects of silvicultural practices result from the equipment and labor costs of silvicultural operations, such as thinning, and the removal of timber from younger stands that can be sold commercially.

There are also important indirect effects that could be of significant benefit over the long run. It appears that properly designed silvicultural treatments will be able to significantly shorten the time needed for the development of suitable habitat in regenerated forests. Such practices would mean that stands would provide suitable habitat for owls for a longer period of time. If widely applied over many decades, particularly in concert with longer rotations and selective harvest techniques, it may be possible to evolve a forest landscape to support a viable owl population with much less reduction in timber harvests than otherwise would be needed.

The variable that most strongly affects the economic benefits of silvicultural treatments is the percent of timber that is removed and sold commercially. The thinning prescriptions specify the density of the stand in trees per acre after thinning. The design of the treatment identifies trees to be cut, leaving sufficient trees to meet the density standard. The design also will specify the percentage of such trees to be removed, left standing, and left on the ground. These design parameters will depend on the characteristics of the stand and the requirements specified for promoting the development of suitable owl habitat.

If no timber is removed during thinning, then the costs of the treatment will not be offset by timber revenues and will need to be borne by agency budgets. Employment will result from the thinning itself, but not from hauling or milling of timber. As the amount of timber removed during thinning is increased, the revenues increase and the employment in hauling and milling logs increases. For each stand, there is a breakeven point which depends on costs of operating on that site, the transportation costs, the diameter of the trees to be removed, and the price of logs. Above the breakeven point, the silvicultural treatment is commercially viable and could be performed under a contract in which the

proceeds from sale of the timber removed cover the costs. Any surplus would be bid away to the benefit of the government if such contracts were auctioned like timber sales.

Estimates of the costs and returns of various silvicultural practices in various types of stands were developed by Chadwick Oliver of the University of Washington (Oliver 1991). The costs and returns per acre for various silvicultural systems are in Table G.1 of Appendix G. A typical regime is the low density system for west side 30-year-old stands. This treatment calls for thinning to 100 trees per acre at age 30 with subsequent removal of 20 trees per acre at age 50 and again at age 70. The total undiscounted costs with no removal of timber are estimated to be about $340 per acre and the returns (above costs) if all thinned threes are removed are estimated to be about $7,165 per acre. Although relatively few trees are removed in the second and third thinnings, most of the returns result from sale of that timber since the trees removed are much larger. If the costs and returns from thinning at ages 50 and 70 are discounted to present value at the time of the first thinning using an 8 percent discount rate, the costs with no removal become $53 per acre and the returns with full removal become $1,109 per acre. In addition, it was estimated that implementing this prescription uses, on average, about 3.64 person-years per acre and could produce a maximum of about 3,833 board feet per acre.

For purposes of estimating the potential economic effects of silvicultural practices within DCAs, the costs and returns for the low density system on 30-year-old stands shown in Table G.1 of Appendix G were assumed to be the end points of a linear relationship starting at 0 percent and ending at 100 percent. It was assumed that 50 percent of the thinned trees would be removed on average.

Estimates of the acreage in DCAs that would be an appropriate target for such practices were developed by using estimates of unsuitable habitat acres in DCAs from the Recovery Team's GIS (geographic information system). Unsuitable habitat in the DCAs accounts for nearly 2.5 million acres. Since only those stands of age 30 to 40 years or less than 11 inches dbh would make good targets, information on the age and size distribution of stands in the national forests and O&C lands was used to determine the percentage of unsuitable habitat likely to be an appropriate age during the 1990s (USDA 1991b,c,d, and USDI 1990). For purposes of estimating the economic effects of silvicultural treatments, it was assumed that 15 percent of unsuitable habitat on Forest Service lands and 30 percent on BLM lands would be appropriate for silvicultural treatment. The resulting target acreage is about 450,000 acres.

Implementation of silvicultural practices to promote development of suitable owl habitat will be the responsibility of the land management agencies, the BLM and Forest Service. The rate of treatment of the target acreage will depend on administrative and budgetary factors that the Recovery Team cannot accurately anticipate. To show the range of potential economic effects from an aggressive program of silvicultural treatment to a go-slow approach, various assumptions were made regarding the percent of target acreage that would be treated in each year during the first decade of the recovery plan implementation.

Estimates for the employment and economic gains from a program of silvicultural treatment in DCAs are in Table H.12. The economic gains are substantial. Even under the assumption that only 50 percent of the thinned trees will be removed, a program treating 50,000 acres per year would yield about 100 million board feet per year and create net benefits of more than $26 million per year. The employment created by such a program also could be significant, about 600 jobs. It is important to note, however, that the wages for thinning

are generally much lower than for commercial harvest and that migrant laborers often are used for such work. If the employment created by a silvicultural program is to benefit workers displaced from the harvesting timber, employment preferences may need to be made a requirement of the contracts let for such work.

5. Estimating the Economic Effects of Salvage.

As described in section III, the recovery plan allows limited salvage within the DCAs. Forest Service and BLM timber salvage sales averaged more than 650 million board feet per year during the 1980s. A rough estimate of the economic effects of allowing salvage was made by assuming an annual potential salvage of 600 million board feet total, of which the DCAs would contain approximately one third. The guidelines for salvage in DCAs are set forth in section III. C. It was assumed that the guidelines would allow 10 to 20 percent of the potential salvage, leaving the rest of the dead trees to contribute to maintenance of habitat conditions. Annual salvage in DCAs could yield 20 to 40 million board feet. The total job coefficients for the timber counties range from eight to just more than 17 jobs per million board feet, averaging 15.7. At the average total job coefficient, salvage in DCAs could support 315 to 630 workers.

6. Estimating the Effects on County Revenues.

In its analysis of the effects of the critical habitat designation, the FWS developed methods to estimate the price effect of restrictions in timber harvest and its effect on the federal receipts from the remaining timber volume. The FWS also worked with the Forest Service and BLM to develop the computational methods needed to allocate the estimated federal timber sale revenues to the counties with which federal receipts are shared. These methods were used to estimate the effects of the DCAs in the recovery plan on the timber revenues that would be received by the counties. These estimates are inTable H.13. These preliminary estimates do not include the effects of asset losses on the tax bases of the counties.

Table H.12. Economic effects of silviculture in designated conservation areas.

Acres Treated Annually	Timber Removed Annually (million board feet)	Employment (jobs)	Annual Economic Benefit ($million)
10,000	19	120	5
25,000	48	302	13
50,000	96	600	26
100,000	192	1200	53

Target Acreage: 450,000 acres currently unsuitable for owl habitat

Table H.13. State and county revenue sharing effects of withdrawing designated conservation areas (DCAs) from the timber base.

State/County	1995 Revenue Share with Final Plans ($hundred)	1995 Revenue Share With DCAs ($hundred)	Percent 1995 Revenue Share Lost	1988-89 County Budget[1] ($hundred)	1995 Revenue Share Lost as Percent of 1988-89 Budget
Washington					
Chelan	$3,602	$2,297	36.23	$14,523	8.99
Clallam	$1,957	$1,192	39.09	$18,543	4.13
Clark	$0	$0	0.00	$58,349	0.00
Cowlitz	$579	$507	12.44	$28,641	0.25
Grays Harbor	$1,314	$800	39.12	$19,059	2.70
Jefferson	$1,640	$998	39.15	$9,098	7.06
King	$991	$106	89.30	$489,751	0.18
Kittitas	$1,123	$640	43.01	$8,851	5.46
Klickitat	$193	$169	12.44	$8,047	0.30
Lewis	$5,810	$4,923	15.27	$25,587	3.47
Mason	$1,248	$760	39.10	$13,723	3.56
Okanogan	$2,196	$3,149	-43.40*	$12,572	-7.58*
Pierce	$354	$38	89.27	$159,516	0.20
Skagit	$1,076	$116	89.22	$26,515	3.62
Skamania	$12,540	$10,982	12.42	$8,549	18.22
Snohomish	$1,806	$194	89.26	$111,247	1.45
Thurston	$0	0	0.00	40,806	0.00
Whatcom	$1,291	$139	89.23	$38,053	3.03
Yakima	$1,870	$646	65.45	$38,078	3.21
Washington Total	**$39,590**	**$27,656**	**30.14**		
Oregon					
Benton	$8,325	$6,566	21.13	$20,125	8.74
Clackamas	$21,242	$18,258	14.05	$98,221	3.04
Columbia	$5,484	$4,185	23.69	$9,434	13.77
Coos	$17,020	$12,740	25.15	$19,515	21.93
Curry	$16,872	$9,550	43.40	$13,323	54.96
Deschutes	$4,789	$3,070	36.02	$22,833	7.57
Douglas	$90,867	$73,501	19.11	$67,062	25.90
Hood River	$2,542	$2,744	-7.95	$7,166	-2.82
Jackson	$44,626	$34,089	23.61	$46,736	22.55
Jefferson	$823	$546	33.66	$4,285	6.46
Josephine	$36,867	$26,117	29.16	$27,870	38.57
Klamath	$15,340	$14,157	7.71	$35,896	3.30
Lane	$79,736	$72,299	9.33	$115,313	6.45
Lincoln	$9,043	$8,936	1.18	$21,343	0.50
Linn	$17,896	$17,274	3.48	$31,525	1.97
Marion	$7,833	$7,278	7.09	$68,306	0.81
Multnomah	$3,792	$3,175	16.27	$211,258	0.29
Polk	$5,819	$4,458	23.39	$11,344	12.00
Tillamook	$5,827	$5,539	4.94	$10,483	2.75
Wasco	$2,023	$2,184	-7.96	$13,260	-1.21
Washington	$1,677	$1,280	23.67	$119,133	0.33
Yamhill	$3,115	$2,680	13.96	$18,313	2.38
Oregon Total	**$401,567**	**$330,626**	**17.67**		
California					
Colusa	$404	$159	60.64	$17,840	1.37
Del Norte	$4,912	$2,472	49.67	$22,026	11.08
Glenn	$1,181	$466	60.54	$29,586	2.42
Humbolt	$6,144	$3,176	48.31	$91,724	3.24
Lake	$1,581	$624	60.53	$52,155	1.83
Mendocino	$1,093	$431	60.57	$166,058	0.40
Shasta	$3,109	$1,395	55.13	$115,323	1.49
Siskiyou	$8,178	$6,262	23.43	$45,310	4.23
Tehama	$1,304	$542	58.44	$40,697	1.87
Trinity	$9,819	$4,616	52.99	$26,697	19.49
California Total	**$37,725**	**$20,143**	**46.61**		
Three-state Total	**$478,882**	**$378,425**	**79.02**		

[A]Projectings. Final forest plans havbe not been released.
*Estimates for Okanogan County Show a gain because the effect of a relatively small reduction in timber harvest is offset by the increase in timber prices.
[1]Data for some counties estimated from 1987-88 data.

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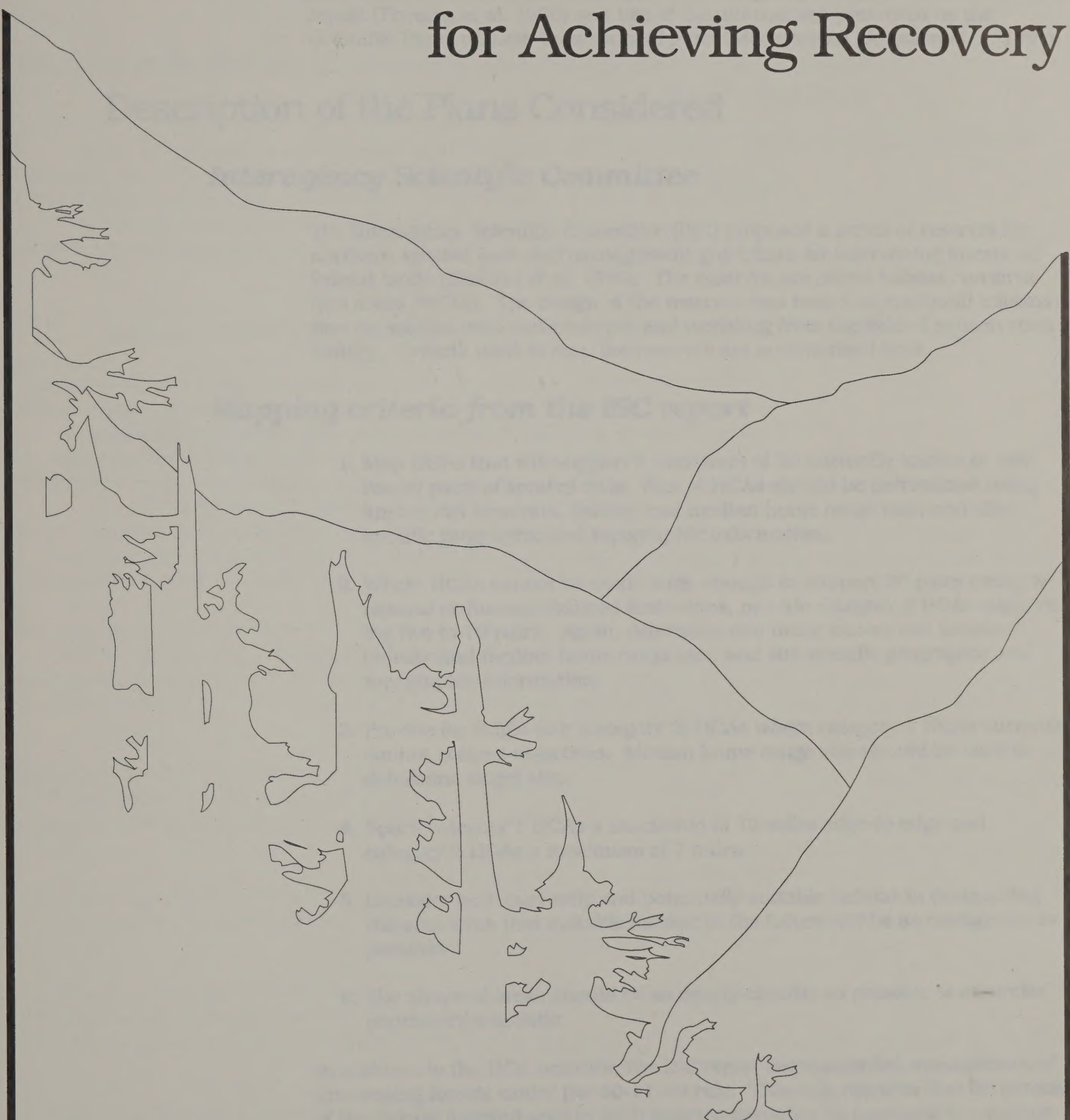
Appendix I

Evaluation of Alternatives for Achieving Recovery



Introduction

This appendix presents the criteria and procedures that were used to delineate the designated conservation areas (DCAs) that form one of the main building blocks of the Northern Spotted Owl Recovery Plan. It also provides information that can be used to compare the effects on federal lands of the recovery plan with other plans proposed for conservation of northern spotted owls or old-growth forests. These plans include the Interagency Scientific Committee report (Thomas et al. 1990) and two of the alternatives presented by the Scientific Panel on Late-Successional Forest Ecosystems (Johnson et al. 1991).

Description of the Plans Considered

Interagency Scientific Committee

The Interagency Scientific Committee (ISC) proposed a series of reserves for northern spotted owls and management guidelines for intervening forests on federal lands (Thomas et al. 1990). The reserves are called habitat conservation areas (HCAs). The design of the reserves was based on empirical information on spotted owls and concepts and modeling from the field of conservation biology. Criteria used to map the reserves are summarized here.

Mapping criteria from the ISC report

1. Map HCAs that will support a minimum of 20 currently known or estimated pairs of spotted owls. Size of HCAs should be determined using known owl locations, density and median home range size, and site-specific geographic and topographic information.

2. Where HCAs cannot be made large enough to support 20 pairs owing to natural or human-induced limitations, provide category 2 HCAs supporting two to 19 pairs. Again, determine size using known owl locations, density and median home range size, and site-specific geographic and topographic information.

3. Provide for single-pair (category 3) HCAs where category 1 HCAs currently cannot achieve objectives. Median home range size should be used to determine target size.

4. Space category 1 HCAs a maximum of 12 miles edge-to-edge and category 2 HCAs a maximum of 7 miles.

5. Consider both currently and potentially suitable habitat in designating the area such that suitable habitat in the future will be as contiguous as possible.

6. The shape of areas should be as nearly circular as possible to minimize perimeter/area ratio.

In addition to the HCA network, the ISC report recommended management of intervening forests under the 50-11-40 rule. This rule requires that 50 percent of the federal forested area in each quarter-township be managed to maintain an average dbh of at least 11 inches and canopy closure of at least 40 percent. This same matrix management rule was proposed for all other options discussed here. The effects of the 50-11-40 rule are not included in this evaluation.

Most significant late successional/old-growth forests

The Scientific Panel on Late-Successional Forest Ecosystems (Johnson et al. 1991) proposed a series of alternatives for managing late successional forests in the Pacific Northwest. One of these (identified as alternative 5) would protect the most ecologically significant blocks of old-growth forest remaining on federal lands. In developing this option, the panel simply mapped the existing units of old forests with no attempt to provide a specific distribution of those blocks.

Most significant late successional/old-growth forests with owl additions

Once the most significant old-growth acres had been mapped, the panel worked with members of the ISC to make additions that then would meet the guidelines used in the HCA network. The resulting network contained all of the most significant old-growth areas with additional acres of spotted owl nesting, roosting, and foraging habitat that met the sizing and spacing criteria used in the ISC report.

Recovery team map (designated conservation areas)

The Northern Spotted Owl Recovery Team delineated a system of designated conservation areas (DCAs) that were modifications of the habitat conservation areas (HCAs). The overall objective of remapping was to provide a level of protection in DCAs at least as high as that provided by ISC mapping while increasing the biological and economic efficiency of the network and effectively providing for other species. Attempts were made to strengthen the DCA network in areas where deficiencies were identified in the HCA network. The fundamental sizing and spacing criteria from the ISC report were applied during mapping of the DCAs. Additional criteria used during this effort follow.

1. Areas were mapped to include as much superior habitat and as many owl locations as possible to achieve a highly effective and efficient network. Where more effective (i.e., more owl locations or better habitat) acres were added to DCAs, opportunities were sought to drop less effective areas so total area did not increase.

2. DCA boundaries were adjusted to accommodate other species' sites where this adjustment could be made without significantly increasing the economic impact of the DCA or significantly decreasing its effectiveness in owl conservation.

3. Areas were mapped to include as high a proportion of reserved land and other land unsuited for timber production as possible where consistent with mapping criteria from the ISC report.

4. Where possible, DCA boundaries were modified to place acres capable of full timber yield back into the timber base and replace them in the DCA with acres from which only partial yields were expected because of forest plan allocations.

5. In areas where the existing network was deficient, attempts were made to provide for new owl clusters and populations with the least possible economic impact.

6. Where possible, boundaries were refined to avoid conflict with other economic development proposals.

The process of mapping DCAs was organized by Recovery Team members and involved biologists from the state wildlife management agencies; biologists and timber managers from each of the affected national forests; and biologists and timber managers from each of the affected BLM districts. Maps used in this process included most or all of the following for each national forest and BLM district:

* Spotted owl location maps,
* Spotted owl nesting, roosting, and foraging habitat maps,
* Maps of lands suitable for timber harvest,
* National forest land management plan allocation maps,
* BLM timber production capability maps,
* Sensitive soils maps,
* ISC habitat conservation area maps,
* Maps of other old forest-associated species and streams with fish at risk (see Appendix D),
* Base maps at a scale of 1/2-inch to the mile.

Documentation was developed to explain why changes were or were not made to HCA boundaries in the process of developing the DCAs. This documentation included additions and deletions of acres of suitable nesting, roosting, and foraging habitat; acres of land suitable for timber production; known spotted owl sites; sites of other old forest-associated species; and acres of various land allocations.

Evaluation of the Options

The options described earlier were evaluated by the Recovery Team to assess their relative biological efficiency. Economic efficiency also was assessed for the DCA and HCA networks as described in Appendix H. Evaluations only assess effects that can be judged from federal lands. A detailed evaluation of nonfederal lands was not done because there was no overall mapping done for recovery options on nonfederal lands.

Biological efficiency of the options was evaluated based on their success in meeting the mapping criteria specified earlier and the biological principles discussed in section III.B. Specific criteria for judging the options were:

1. The number of designated areas that currently contain at least 20 known pairs of owls, and thus have high likelihood of persisting for at least 100 years.

2. The number of designated areas that contain sufficient potential habitat to be able to support 20 pairs of owls in the future.

3. The total number of acres of nesting, roosting, and foraging habitat included in designated areas.

4. The total number of known pairs of owls included in designated areas.

5. Nearest-neighbor distances of the designated areas. Complete information on nearest-neighbor distances is not available at this time so is not included.

6. The number of sites for other old forest-associated species and miles of streams included in designated areas.

Information from the geographic information system (GIS) data base was used

to evaluate options. Information in this base included acres of nesting, roosting and foraging habitat data for most federal lands (see Appendix J); known locations for owl pairs verified during the period 1986 through 1990; lands suitable for timber production for all national forests and BLM districts; lands that have been reserved from timber harvest by Congressional authority; land ownership data; and locations of other old forest-associated species (see Appendix D).

The evaluations are presented in Tables I.1 to I.11. Tables I.1 through I.4 present summary information for each strategy. This includes: 1) total federal acres included in the strategy; 2) the number of those acres that are reserved from timber harvest by Congressional action; 3) the number of acres, otherwise suitable for timber production, that are included in conservation areas; 4) the number of acres of spotted owl nesting, roosting, and foraging (NRF) habitat; 5) the percent of the conservation areas composed of NRF habitat; and 6) the number of spotted owl pair locations confirmed inside the boundaries of the areas between 1986 and 1990. These data are divided by state and individual federal agency.

Tables I.5 through I.7 present information on the size of conservation areas included in each of the options. Numbers shown are the numbers of areas that fall into each of a series of size class categories. Again, only federal lands are tallied in these tables. Tables I.8 through I.10 show a frequency distribution of conservation areas for each strategy based on the number of spotted owl pair locations. Table I.11 shows the number of sites of other old forest-associated species included in conservation areas for each of the strategies.

Tables I.1 through I.4 show that DCAs contain approximately 275,000 more acres of NRF habitat than do the HCAs. Approximately 120 more owl pairs have been located in the DCAs than in the HCAs. Approximately 80,000 more acres suitable for timber production are contained in DCAs than in HCAs. The most significant late successional/old-growth (LSOG) areas contain about 100 and 200 fewer known pair locations than do the HCAs and DCAs respectively. However, this figure is somewhat misleading since reserved lands were not mapped into these units. If known pair locations in reserved lands were added to the tally for the LSOG units, the total would be very close to that observed for the HCAs. However, under the LSOG strategy, fewer of these owls would be contained in large, contiguous conservation areas. NRF habitat acres in the LSOGs are fewer than in the HCA or DCA mapping. Again, this figure is misleading because reserves were not mapped into the LSOGs. The addition of NRF habitat acres from reserves would increase the tally for LSOGs, but few of these acres would be present within large, contiguous conservation areas. The most significant late successional/old-growth with owl additions (LSOG + owl additions) contains more pair locations, more NRF habitat, and more acres suitable for timber production than the other three options. Thus, it is more effective for owls but is also a more costly option.

The data in Tables I.5 through I.7 can be used to determine the approximate number of areas that might have the capability to support at least 20 pairs of owls if habitat recovered in these areas. Data from tables in Appendix J suggest that areas of approximately 40,000 to 50,000 acres in Oregon and California may develop the capability to support 20 pairs of owls. Areas of 70,000 to 80,000 acres in Washington may develop this capability. Based on these criteria, approximately 60 conservation areas would be capable of supporting at least 20 pairs of owls on federal lands in the future under both the HCA and DCA strategies. Approximately 50 such areas would be provided in the LSOG + owl additions strategy, and 40 areas in the LSOG strategy.

Tables I.8 through I.10 clearly demonstrate the difficulty of finding areas that currently support at least 20 pairs of owls on federal lands. This reflects the fragmented condition of owl populations and owl habitat in the landscape. Based on current owl locations in the GIS, 11 such areas are included in the DCA network; 9 in the HCA network; 18 in the LSOG + owl addition strategy; and 11 in the LSOG strategy. Again, it should be noted that these numbers are based solely on GIS analysis and do not include updates that were made to tables in Appendix J or tables presented in Thomas et al. (1990). Numbers were used straight from the GIS to provide the most valid basis for comparison across options.

Table I.11 presents information on other species locations within each of the conservation area networks. The numbers of locations (nest sites, areas of observation) for bald eagles, marten, and fisher did not vary much among the different options. The number of goshawk nest sites varied from 82 to 122, and the largest number of these sites was in the DCAs of the recovery plan. The number of occupied murrelet sites varied from 155 to 227, and the largest number of these sites was in the DCAs of the recovery plan. The lowest number of occupied sites for murrelets was in the HCAs. Most of the additional benefits to murrelets occur on the Oregon coast where 60 murrelet sites were in one DCA. The number of miles of streams with fish stocks at risk varied from 1,189 for the late successional old-growth option to 2,118 for the HCAs. The DCAs of the recovery plan included 2,047 miles of stream with fish stocks at risk. Most of the stream reaches included in the options were in the upper parts of the drainages, and many of these streams will likely require additional attention in the future.

Table I.1. Estimated acres and owl locations for category 1, 2, and 3 habitat conservation areas (HCAs) under the ISC strategy.

Ownership	Total Acres	Reserved Acres	Timber Acres	NRF[1] Habitat	Percent Habitat	Pairs
CALIFORNIA						
U.S. Forest Service	1,533,655	373,784	891,200	522,320	34.06	247
National Park Service	115,310	115,310	0	.	.	7
U.S. Bureau of Land Management	161,466	.	161,466	.	.	8
Total federal	**1,810,430**	**489,093**	**1,052,666**	**522,320**	**.**	**262**
OREGON						
U.S. Forest Service	1,936,761	468,202	947,440	1,031,080	53.24	378
National Park Service	938	938	0	523	55.77	.
U.S. Bureau of Land Management	806,335	6,069	806,335	353,000	43.78	274
Total federal	**2,744,034**	**475,209**	**1,753,775**	**1,384,603**	**49.10**	**652**
WASHINGTON						
U.S. Forest Service	2,302,110	475,882	943,960	1,174,400	51.01	242
National Park Service	575,996	575,996	0	306,304	53.18	17
Other federal	79,188	0	0	0	0	.
Total federal	**2,957,293**	**1,051,877**	**943,960**	**1,480,704**	**50.10**	**259**
RANGEWIDE						
U.S. Forest Service	5,772,525	1,317,868	2,782,600	2,727,800	47.25	867
National Park Service	692,243	692,243	0	306,827	44.32	24
Bureau of Land Management	967,801	6,069	967,801	353,000	36.47	282
Other federal	79,188	0	0	0	0	.
Total federal	**7,511,757**	**2,016,180**	**3,750,401**	**3,387,627**	**.**	**1,173[2]**

[1] Nesting, roosting, and foraging
[2] 28 additional owl pairs have been located on reserved lands outside the HCA network
Dot (.) = unknown

Table I.2. Estimated acres and owl locations for category 1 and 2 designated conservation areas (DCAs) and reserved pair areas under the recovery plan strategy.

Ownership	Total Acres	Reserved Acres	Timber Acres	NRF[1] Habitat	Percent Habitat	Pairs[2]
CALIFORNIA						
U.S. Forest Service	1,553,678	384,770	872,758	526,570	33.55	277
National Park Service	115,312	115,312	0	.	.	7
U.S. Bureau of Land Management	119,646	0	119,646	.	.	8
Total federal	**1,788,636**	**500,082**	**992,404**	**526,570**	.	**292**
OREGON						
U.S. Forest Service	2,181,730	526,467	1,054,912	1,170,112	53.64	435
National Park Service	872	872	0	510	58.49	.
U.S. Bureau of Land Management	804,114	6,064	804,114	348,304	43.44	265
Total federal	**2,986,716**	**533,403**	**1,859,026**	**1,518,926**	**50.90**	**700**
WASHINGTON						
U.S. Forest Service	2,415,079	489,356	1,000,076	1,313,858	54.63	287
National Park Service	568,570	568,570	0	304,020	53.47	17
Other Federal	79,188	0	0	0	.	.
Total federal	**3,062,837**	**1,057,927**	**1,000,076**	**1,617,878**	**52.80**	**304**
RANGEWIDE						
U.S. Forest Service	6,150,487	1,400,593	2,927,746	3,010,540	48.95	999
National Park Service	684,754	684,754	.	304,530	44.47	24
U.S. Bureau of Land Management	923,760	6,064	923,760	348,304	37.70	273
Other federal	79,188	0	0	0	0	.
Total federal	**7,838,189**	**2,091,412**	**3,851,506**	**3,663,374**	.	**1,296[3]**

[1] Nesting, roosting, and foraging

[2] These numbers are from the geographic information system for comparison with other alternatives. They may not exactly equal numbers reported in main body of draft recovery plan because they do not include adjustments made in the plan.

[3] 28 additional pairs have been located in reserved lands outside of the DCA network and 19 additional pairs located in managed pair areas.

Dot (.) = unknown

Table I.3. Estimated acres and owl locations for the most significant old-growth units mapped by the Scientific Panel on Late-Successional Forest Ecosystems.

Ownership	Total Acres	Reserved Acres	Timber Acres	NRF[1] Habitat	Percent Habitat	Pairs
CALIFORNIA						
U.S. Forest Service	1,003,734	0	738,880	381,080	37.97	198
U.S. Bureau of Land Management	440	0	440	.	.	.
Total federal	**1,004,174**	**0**	**739,320**	**381,080**	**.**	**198**
OREGON						
U.S. Forest Service	1,917,730	0	1,147,840	1,037,080	54.08	457
U.S. Bureau of Land Management	671,274	0	671,274	345,480	51.47	249
Total federal	**2,589,004**	**0**	**1,819,114**	**1,382,560**	**53.40**	**706**
WASHINGTON						
U.S. Forest Service	1,514,164	0	681,720	814,080	53.76	187
Total federal	**1,514,164**	**0**	**681,720**	**814,080**	**53.76**	**187**
RANGEWIDE						
U.S. Forest Service	4,435,628	0	2,568,440	2,232,240	50.33	842
U.S. Bureau of Land Management	671,713	0	671,713	345,480	51.43	249
Total federal	**5,107,342**	**0**	**3,240,153**	**2,577,720**	**50.50**	**1,091[2]**

[1] Nesting, roosting, and foraging
[2] 131 additional pairs have been located in reserved lands outside the most significant old-growth units.
Dot (.) = unknown

Table I.4. Estimated acres and owl locations for the most significant old-growth units plus owl additions mapped by the Scientific Panel on Late-Successional Forest Ecosystems.

Ownership	Total Acres	Reserved Acres	Timber Acres	NRF[1] Habitat	Percent Habitat	Pairs
CALIFORNIA						
U.S. Forest Service	1,551,686	380,269	869,240	549,000	35.38	252
U.S. Bureau of Land Management	97,429	.	97,429	0	.	4
Total federal	**1,649,115**	**380,269**	**966,669**	**549,000**	.	**256**
OREGON						
U.S. Forest Service	2,776,300	477,863	1,390,760	1,450,760	52.26	554
National Park Service	3,656	3,656	0	2,733	74.75	.
U.S. Bureau of Land Management	722,410	0	722,410	337,440	46.71	251
Total federal	**3,502,366**	**481,519**	**2,113,170**	**1,790,933**	**51.10**	**805**
WASHINGTON						
U.S. Forest Service	2,397,937	322,849	1,039,760	1,211,640	50.53	259
National Park Service	582,244	582,244	0	355,825	61.11	19
Total federal	**2,980,181**	**905,093**	**1,039,760**	**1,567,465**	**52.60**	**278**
RANGEWIDE						
U.S. Forest Service	6,725,923	1,180,981	3,299,760	3,211,400	47.75	1,065
National Park Service	585,900	585,900	0	358,558	61.20	19
U.S. Bureau of Land Management	819,839	0	819,839	337,440	41.16	255
Total federal	**8,131,662**	**1,766,881**	**4,119,599**	**3,907,398**	.	**1,339[2]**

[1] Nesting, roosting, and foraging
[2] 54 additional owl pairs have been located in reserved lands outside of the most significant old-growth and owl addition units
Dot (.) = unknown

Table I.5. Size class distribution of conservation units under various spotted owl conservation strategies in the State of California.

	Number of Conservation Areas By Size Class (In Acres)								
Alternative	Less than 10,000	10 to 20,000	20 to 30,000	30 to 40,000	40 to 50,000	50 to 60,000	60 to 70,000	[1]More than 80,000	Total Units
DCA	51	6	5	6	3	4	3	6	84
HCA	48	8	3	3	7	4	3	5	81
LSOG+OWL	40	4	2	1	4	0	2	7	60
LSOG	27	6	2	1	1	3	3	3	46

[1]No areas between 70,000 and 80,000 acres were located in California

DCA = designated conservation area
HCA = habitat conservation area delineated by ISC
LSOG+OWL = most significant old-growth units plus owl additions
LSOG = most significant old-growth units

Table I.6. Size class distribution of conservation units under various spotted owl conservation strategies in the State of Oregon.

Number of Conservation Areas By Size Class (In Acres)

Alternative	Less than 10,000	10 to 20,000	20 to 30,000	30 to 40,000	40 to 50,000	50 to 60,000	60 to 70,000	70 to 80,000	More than 80,000	Total Units
DCA	16	3	5	5	6	5	7	5	10	62
HCA	6	4	2	3	4	7	8	6	8	48
LSOG+OWL	43	8	4	3	8	4	3	1	14	88
LSOG	65	19	8	4	7	3	6	4	5	121

DCA = designated conservation area
HCA = habitat conservation area delineated by ISC
LSOG+OWL = most significant old-growth units plus owl additions
LSOG = most significant old-growth units

Table I.7. Size class distribution of conservation units under various spotted owl conservation strategies in the State of Washington.

Number Of Conservation Areas By Size Class (In Acres)

Alternative	Less than 10,000	10 to 20,000	20 to 30,000	30 to 40,000	40 to 50,000	50 to 60,000	60 to 70,000	70 to 80,000	More than 80,000	Total Units
DCA	3	13	8	7	2	3	2	2	10	50
HCA	4	10	4	4	3	2	2	2	11	42
LSOG+OWL	15	11	4	7	3	3	1	1	8	53
LSOG	25	19	9	7	4	2	2	1	1	70

DCA = designated conservation area
HCA = habitat conservation area delineated by ISC
LSOG+OWL = most significant old-growth units plus owl additions
LSOG = most significant old-growth units

Table I.8. Frequency distribution of conservation areas based on number of known owl pair locations on federal land. Data are presented for various spotted owl conservation strategies for California.

Alternative	Number of Areas that Fall Within Specified Ranges of Numbers of Known Owl Pair Locations (only owl locations on federal lands were tallied)						
	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	More than 25	Total[1]
DCA[2]	32	8	5	1	0	2	48
HCA	28	8	3	2	0	2	43
LSOG+OWL	17	4	2	1	2	3	29
LSOG	22	4	3	1	1	1	32

[1]Only areas that contain known owl locations are reported in the table; totals do not equal the total number of areas.
[2]These numbers were taken directly from the geographic information system for comparison with other options. They may not match numbers reported in the main body of the draft recovery plan because they do not include adjustments made in the plan.

DCA = designated conservation area
HCA = habitat conservation area delineated by ISC
LSOG+OWL = most significant old-growth units plus owl additions
LSOG = most significant old-growth units

Table I.9. Frequency distribution of conservation areas based on number of known owl pair locations on federal land. Data are presented for various spotted owl conservation strategies for Oregon.

Alternative	Number of Areas that Fall Within Specified Ranges of Numbers of Known Owl Pair Locations (only owl locations on federal lands were tallied)						
	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	More than 25	Total[1]
DCA[2]	18	12	8	9	4	4	55
HCA	14	9	7	11	3	3	47
LSOG+OWL	40	8	8	6	3	8	73
LSOG	59	13	11	3	4	5	95

[1]Only areas that contain known owl locations are reported in the table; totals do not equal the total number of areas.
[2]These numbers were taken directly from the geographic information system for comparison with other options. They may not match numbers reported in the main body of the draft recovery plan because they do not include adjustments made in the plan.

DCA = designated conservation area
HCA = habitat conservation area delineated by ISC
LSOG+OWL = most significant old-growth units plus owl additions
LSOG = most significant old-growth units

Table I.10. Frequency distribution of conservation areas based on number of known owl pair locations on federal land. Data are presented for various spotted owl conservation strategies for Washington.

Alternative	Number of Areas that Fall Within Specified Ranges of Numbers of Known Owl Pair Locations (only owl locations on federal lands were tallied)						
	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	More than 25	Total[1]
DCA[2]	28	11	3	1	0	1	44
HCA	21	7	1	3	0	1	33
LSOG+OWL	36	10	1	0	0	2	49
LSOG	42	10	2	0	0	0	54

[1]Only areas that contain known owl locations are reported in the table; totals do not equal the total number of areas.
[2]These numbers were taken directly from the geographic information system for comparison with other options. They may not match numbers reported in the main body of the draft recovery plan because they do not include adjustments made in the plan.

DCA = designated conservation area
HCA = habitat conservation area delineated by ISC
LSOG+OWL = most significant old-growth units plus owl additions
LSOG = most significant old-growth units

Table I.11. Number of locations of other species and miles of streams (with fish stocks at risk) in different conservation options for the northern spotted owl.

Conservation Strategy	Species					Miles of Streams
	Bald Eagle	Fisher	Goshawk	Marten	Murrelet	
DCA	40	37	122	60	227	2,047
HCA	45	38	111	51	155	2,118
LSOG+OWL	40	40	114	63	205	1,968
LSOG	33	32	82	49	177	1,189

DCA = designated conservation area
HCA = habitat conservation area delineated by ISC
LSOG+OWL = most significant old-growth units plus owl additions
LSOG = most significant old-growth units

Literature Cited

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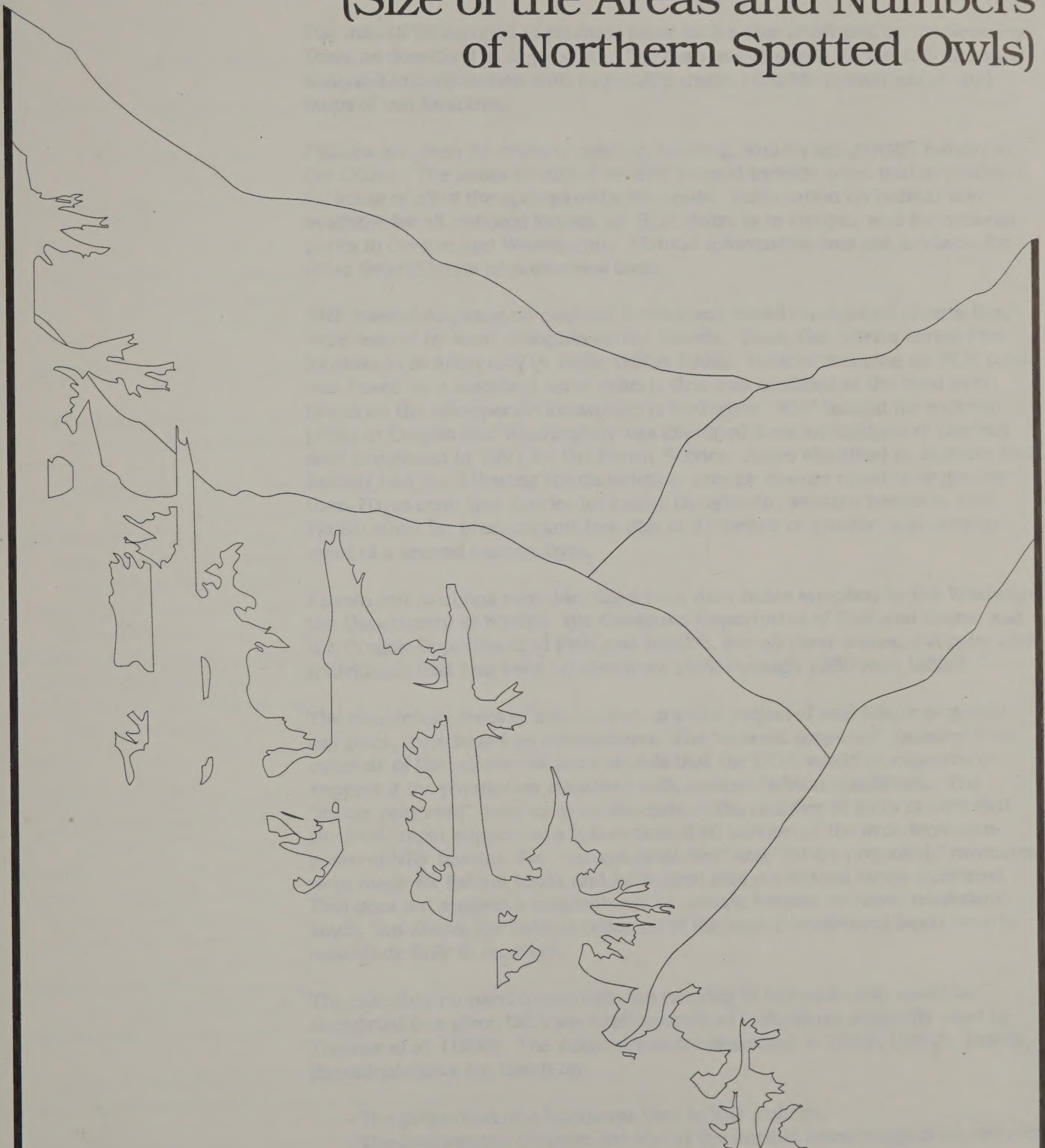
Johnson, K.N., J.F. Franklin, J.W. Thomas, and J. Gordon. 1991. Alternatives for management of late-successional forests of the Pacific Northwest. A report to the Agriculture Committee and the Merchant Marine and Fisheries Committee of the U.S. House of Representatives. 59 pages.

Appendix J

Designated Conservation Areas
(Size of the Areas and Numbers of Northern Spotted Owls)



Introduction

This appendix presents detailed information on the individual designated conservation areas (DCAs). Tables show the size of the areas, the current condition of habitat within them, the current number of known northern spotted owls, and projections of the near-term and future capability of these areas to support owls. The tables are based on data stored in the geographic information system (GIS) at the Oregon State Service Center in Salem, Oregon.

The map of DCAs used to produce these tables was developed by the Recovery Team as described in Appendix I. The map was digitized for the GIS and then analyzed in conjunction with ownership maps, suitable habitat maps, and maps of owl locations.

Figures are given for acres of nesting, roosting, and foraging (NRF) habitat in the DCAs. The areas identified as NRF habitat include acres that are suitable for some or all of the spotted owl's life needs. Information on habitat was available for all national forests, all BLM districts in Oregon, and for national parks in Oregon and Washington. Habitat information was not available for other federal lands or nonfederal lands.

NRF habitat mapping on national forests was based on regional criteria that were refined by local biologists on the forests. Thus, the criteria varied from location to location (USDA 1988; USDA 1992). Habitat mapping on BLM lands was based on a standard set of criteria that was modified at the local level based on the site-specific knowledge of biologists. NRF habitat for national parks in Oregon and Washington was identified from an analysis of Landsat data completed in 1991 for the Forest Service. Acres identified as suitable NRF habitat had the following characteristics: canopy closure equal to or greater than 70 percent; tree species including Douglas-fir, western hemlock, and Pacific silver fir; predominant tree dbh of 21 inches or greater; and development of a second canopy layer.

Known owl locations were identified from data bases supplied by the Washington Department of Wildlife, the California Department of Fish and Game, and the Oregon Department of Fish and Wildlife. For all three states, owl pairs and individuals that had been verified from 1986 through 1990 were tallied.

The remaining pieces of information, current projected and future projected owl pairs, were based on calculations. The "current projected" number is an estimate of the number of pairs of owls that the DCA would be expected to support if the population stabilized with current habitat conditions. The "future projected" number is an estimate of the number of pairs of owls that the DCA might support at a future time if 80 percent of the area were composed of NRF habitat. For "current projected" and "future projected," estimates were made for federal lands and for federal and nonfederal lands combined. This does not suggest a commitment to provide habitat on those nonfederal lands, but shows the habitat potential of the area if nonfederal lands were to contribute fully to recovery.

The calculations used to estimate the number of owl pairs that could be supported in a given DCA were refinements of techniques originally used by Thomas et al. (1990). The refinements are described in USDA (1992). Briefly, the calculations are based on:

- The proportion of a landscape that is NRF habitat,
- The relationship between the size of the annual home range of an owl pair and the percentage of that home range in NRF habitat,

- The overlap of home ranges among adjacent pairs of owls,
- A correction for expected long-term occupancy of sites based on the influence of local population size and proportion of suitable habitat in the landscape.

Two regressions were developed to relate the size of annual pair home ranges to the proportion of area in NRF habitat. One was based on data from Washington and the second was based on data from Oregon and California combined.

The Washington regression was:

home range (acres) = 18,364-(17,607 x proportion habitat)

For California and Oregon, the regression was:

home range (acres) = 8,688-(7,054 x proportion habitat)

The proportion habitat term in these equations varies from zero to one.

Calculated home ranges were reduced by 30 percent to account for overlap of adjacent spotted owl pairs.

The following procedure was used to calculate the estimated number of pairs that could be supported in a DCA given current habitat conditions. These are the figures reported as current projected pairs in the tables.

1. GIS information was used to determine the total size of the DCA and the current proportion of NRF habitat.
2. The proportion of NRF habitat was used in the regression equations to calculate home range size. The regression result was reduced by 30 percent to account for home range overlap.
3. The resulting home range size was divided into the total DCA size to determine the number of potential pair sites in the DCA.
4. The estimated pair sites were adjusted for the proportion that would likely remain occupied over time using an updated table from Thomas et al. (1990). This table was updated by Voss and Noon (pers. comm.) and predicts the number of sites that would remain occupied over time given an initial number of locally interacting pairs and the proportion of the area in NRF habitat. For the estimate of current projected pairs, it was assumed that populations in DCAs were still part of a larger interacting population, i.e., that there is still an owl population in the matrix that interacts with the population in the DCA. The occupancy correction factor for these projections reflected this assumption.

The same basic procedure was used to estimate future projected pairs. For this calculation, it was assumed that 80 percent of the DCA would exist as NRF habitat at some future point in time. The assumption of 80 percent reflects (1) an assumption that not all area in any DCA is capable of supporting NRF habitat, and (2) an assumption that natural disturbances always would maintain some portion of the forests in each DCA in younger age classes. It also was assumed that the DCA would operate as a cluster at least partially isolated from other populations since other habitat surrounding the DCA would be managed for dispersal rather than for breeding pairs of owls. Therefore, the correction factor used in the occupancy table was based on the number of pair sites calculated for the area (see step 3 in the previous discussion).

Once the calculations were complete, the current projected and future projected numbers were further refined by state agency biologists based on local knowledge of site conditions.

Abbreviations and Definitions Used in Tables J.1. through J.11.

BLM = lands managed by the U.S. Bureau of Land Management
NFS = lands in the national forests managed by the U.S. Forest Service
NPS = lands in the national parks managed by the National Park Service
OTHER FED = other federal lands; national wildlife refuges; Department of Defense Military Reservations
NRF = nesting, roosting, and foraging habitat for spotted owls

Current projected = an estimate of the number of pairs of owls that the DCA would be expected to support if the population stabilized with current habitat conditions. This number may be either higher or lower than the current known, due to lack of survey information or recent loss of habitat in the vicinity, respectively. Current known numbers of owls may be artifically high due to displacement from surrounding habitat which was harvested recently or because of its proximity to source populations.

Future projected = an estimate of the number of pairs of owls that the DCA might support in the future if DCAs were composed of 80 percent NRF habitat. This estimate includes nonfederal lands within the DCA boundaries. This does not suggest a commitment to provide habitat on those nonfederal lands. See section III.C.4. for discussion of management of these lands.

Note that owl numbers with the tables are split only by federal and nonfederal ownership. Specific numbers for each category of federal ownership are not shown.

Table J.1. Acreage and owl numbers for designated conservation areas in the Olympic Peninsula province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
WD-36	NFS	219,360	439,390				
	NPS	227,159	381,025				
	TOTAL FED	446,519	820,415	84	14	124	193
	TOTAL	-	847,086	86	14	124	193
WD-45	NPS	-	35,439				
	TOTAL FED	-	35,439	5	1	8	8
	TOTAL	-	35,439	5	1	8	8
	PROVINCE TOTAL FED		855,854	89	15	132	201
	PROVINCE TOTAL	-	882,525	91	15	132	201

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Table J.2. Acreage and owl numbers for the designated conservation area in the western Washington lowlands province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
WD-43	OTHER FED	-	79,188				
	TOTAL FED	-	79,188	0	0	0	21
	TOTAL	-	81,590	0	0	0	21
	PROVINCE TOTAL FED		79,188	0	0	0	21
	PROVINCE TOTAL	-	81,590	0	0	0	21

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Table J.3. Acreage and owl numbers for designated conservation areas in the western Washington Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-1	NFS	92,280	147,312				
	TOTAL FED	92,280	147,312	15	1	23	41
	TOTAL	-	153,631	16	1	24	41
WD-2	NFS	83,240	111,669				
	TOTAL FED	83,240	111,669	14	0	25	31
	TOTAL	-	111,756	14	0	25	31
WD-2N	NFS	33,560	48,202				
	TOTAL FED	33,560	48,202	8	0	10	12
	TOTAL	-	52,239	8	0	10	12
WD-2W	NFS	10,040	16,112				
	TOTAL FED	10,040	16,112	3	0	3	2
	TOTAL	-	16,781	3	0	3	2
WD-3	NFS	73,520	132,393				
	NPS	29,775	38,961				
	TOTAL FED	103,295	171,354	16	0	23	45
	TOTAL	-	175,414	16	0	23	45
WD-4	NFS	49,280	99,001				
	NPS	6,721	10,260				
	TOTAL FED	56,001	109,260	10	1	14	30
	TOTAL	-	133,304	12	1	16	36
WD-8	NFS	44,120	84,360				
	TOTAL FED	44,120	84,360	6	1	11	24
	TOTAL	-	87,945	6	1	11	24
WD-9	NFS	57,480	100,884				
	NPS	768	1,042				
	TOTAL FED	58,248	101,925	10	0	14	28
	TOTAL	-	104,211	10	0	14	28
WD-10	NFS	14,880	32,358				
	TOTAL FED	14,880	32,358	4	1	5	8
	TOTAL	-	54,737	4	1	7	14

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continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-11	NFS	1,120	6,697				
	NPS	3,710	5,762				
	TOTAL FED	4,830	12,459	1	0	1	1
	TOTAL	-	12,535	1	0	1	1
WD-17	NFS	7,400	15,648				
	TOTAL FED	7,400	15,648	1	0	3	2
	TOTAL	-	29,740	1	0	3	6
WD-18	NFS	11,880	25,170				
	TOTAL FED	11,880	25,170	2	1	3	5
	TOTAL	-	27,331	2	1	3	5
WD-19	NFS	19,560	35,176				
	TOTAL FED	19,560	35,176	1	5	7	9
	TOTAL	-	38,404	1	5	7	9
WD-19W	NFS	6,840	12,673				
	TOTAL FED	6,840	12,673	2	0	3	3
	TOTAL	-	13,517	2	0	3	3
WD-25	NFS	17,320	30,753				
	TOTAL FED	17,320	30,753	3	0	5	8
	TOTAL	-	31,273	3	0	5	8
WD-26	NFS	12,640	23,081				
	TOTAL FED	12,640	23,081	3	0	4	5
	TOTAL	-	23,081	3	0	4	5
WD-26W	NFS	8,720	14,248				
	TOTAL FED	8,720	14,248	2	0	3	3
	TOTAL	-	14,310	2	0	3	3
WD-27	NFS	16,760	32,671				
	TOTAL FED	16,760	32,671	4	1	5	8
	TOTAL	-	33,360	4	1	5	8
WD-27S	NFS	6,480	9,285				
	TOTAL FED	6,480	9,285	1	0	2	2
	TOTAL	-	9,677	1	0	2	2

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-28	NFS	51,360	76,718				
	TOTAL FED	51,360	76,718	6	2	14	20
	TOTAL	-	76,925	6	2	14	20
WD-29	NFS	18,840	26,392				
	TOTAL FED	18,840	26,392	2	0	5	5
	TOTAL	-	26,414	2	0	5	5
WD-30	NFS	9,520	14,423				
	TOTAL FED	9,520	14,423	4	0	4	3
	TOTAL	-	14,424	4	0	4	3
WD-31	NFS	19,200	27,016				
	NPS	223	292				
	TOTAL FED	19,423	27,308	1	0	5	6
	TOTAL	-	27,386	1	0	5	6
WD-32	NFS	18,920	37,487				
	NPS	157	258				
	TOTAL FED	19,077	37,745	2	0	4	9
	TOTAL	-	37,995	2	0	4	9
WD-34	NFS	1,920	12,184				
	NPS	25,992	75,476				
	TOTAL FED	27,912	87,660	0	0	7	10
	TOTAL	-	87,698	0	0	7	10
WD-35	NPS	5,435	14,443				
	TOTAL FED	5,435	14,443	0	0	2	2
	TOTAL	-	14,448	0	0	2	2
	PROV TOT FED	759,661	1,318,405	121	12	205	322
	PROVINCE TOTAL		1,408,536	124	12	210	338

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Table J.4. Acreage and owl numbers for designated conservation areas in the eastern Washington Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
WD-1N	NFS	25,640	34,197				
	TOTAL FED	25,640	34,197	6	0	8	8
	TOTAL	-	34,525	6	0	8	8
WD-5	NFS	33,240	53,560				
	TOTAL FED	33,240	53,560	9	2	11	14
	TOTAL	-	88,136	11	2	13	24
WD-6	NFS	54,520	85,853				
	TOTAL FED	54,520	85,853	12	1	16	24
	TOTAL	-	92,263	12	1	17	26
WD-7	NFS	58,960	102,030				
	TOTAL FED	58,960	102,030	7	1	15	28
	TOTAL	-	112,052	7	1	16	31
WD-12	NFS	29,280	62,226				
	TOTAL FED	29,280	62,226	8	0	8	16
	TOTAL	-	64,439	8	0	8	16
WD-14	NFS	3,520	11,294				
	TOTAL FED	3,520	11,294	2	0	2	2
	TOTAL	-	11,305	2	0	2	2
WD-15	NFS	33,400	50,733				
	TOTAL FED	33,400	50,733	2	0	9	13
	TOTAL	-	52,167	3	0	9	13
WD-16	NFS	31,640	44,804				
	TOTAL FED	31,640	44,804	8	6	9	11
	TOTAL	-	60,639	8	6	14	16
WD-20	NFS	9,120	24,904				
	TOTAL FED	9,120	24,904	3	0	3	5
	TOTAL	-	26,668	3	0	3	5
WD-21	NFS	4,680	17,552				
	TOTAL FED	4,680	17,552	6	0	6	5
	TOTAL	-	24,572	6	0	6	5
WD-22	NFS	1,680	7,554				
	TOTAL FED	1,680	7,554	2	0	2	2
	TOTAL	-	11,107	2	0	2	2
WD-23	NFS	6,440	11,302				
	TOTAL FED	6,440	11,302	1	0	2	3
	TOTAL	-	13,222	2	0	2	3

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
WD-24	NFS	37,760	68,537				
	TOTAL FED	37,760	68,537	5	0	10	18
	TOTAL	-	68,544	6	0	10	18
WD-33	NFS	1,520	11,860				
	NPS	4.080	41,052				
	TOTAL FED	5,600	52,912	2	0	6	10
	TOTAL	-	55,176	2	0	6	10
WD-37	NFS	1,400	16,369				
	TOTAL FED	1,400	16,369	1	0	2	2
	TOTAL	-	16,935	1	0	2	2
WD-38	NFS	3,040	23,878				
	TOTAL FED	3,040	23,878	3	0	3	4
	TOTAL	-	23,878	3	0	3	4
WD-39	NFS	1,920	11,480				
	TOTAL FED	1,920	11,480	1	0	1	2
	TOTAL	-	11,480	1	0	1	2
WD-40	NFS	4,880	20,104				
	TOTAL FED	4,880	20,104	1	0	2	2
	TOTAL	-	20,104	1	0	2	2
WD-41	NFS	3,480	12,803				
	TOTAL FED	3,480	12,803	1	0	1	2
	TOTAL	-	12,803	1	0	1	2
WD-42	NFS	11,200	26,245				
	TOTAL FED	11,200	26,245	3	0	3	5
	TOTAL	-	26,245	3	0	3	5
WD-44	NFS	3,000	9,962				
	TOTAL FED	3,000	9,962	1	0	1	1
	TOTAL	-	9,962	1	0	1	1
	PROV TOT FED	364,400	748,299	84	5	120	176
	PROVINCE TOTAL	-	836,222	85	5	129	196

[a] The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Table J.5. Acreage and owl numbers for designated conservation areas in the Oregon Coast Range province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
OD-27	BLM	27,320	51,832				
	TOTAL FED	27,320	51,832	15	2	12	20
	TOTAL	-	77,749	16	3	13	30
OD-28	BLM	26,720	48,486				
	TOTAL FED	26,720	48,486	19	7	15	20
	TOTAL	-	70,663	24	10	18	27
OD-29	NFS	18,480	24,870				
	BLM	9,880	16,472				
	TOTAL FED	28,360	41,343	9	2	10	15
	TOTAL	-	50,636	10	2	10	18
OD-30	BLM	15,760	34,034				
	TOTAL FED	15,760	34,034	14	1	10	12
	TOTAL	-	59,934	18	3	13	23
OD-31	NFS	21,840	41,353				
	BLM	9,920	18,141				
	TOTAL FED	31,760	59,494	14	3	14	20
	TOTAL	-	70,555	14	4	14	25
OD-32	NFS	4,600	8,297				
	BLM	10,400	21,578				
	TOTAL FED	15,000	29,874	5	1	5	10
	TOTAL	-	39,894	5	1	5	16
OD-33	NFS	6,560	15,771				
	BLM	3,080	20,814				
	TOTAL FED	9,640	36,586	5	0	5	12
	TOTAL	-	60,175	5	0	5	23
OD-34	NFS	24,600	44,328				
	BLM	-	350				
	TOTAL FED	24,600	44,678	7	1	7	15
	TOTAL	-	50,661	7	1	7	18
OD-35	NFS	17,360	40,889				
	BLM	440	3,707				
	TOTAL FED	17,800	44,595	3	2	3	15
	TOTAL	-	51,780	3	2	3	18

continues—

continued—

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-36	NFS	5,160	14,898				
	BLM	4,600	38,520				
	TOTAL FED	9,720	53,418	3	0	3	18
	TOTAL	-	70,212	3	1	3	25
OD-37	BLM	2,920	26,780				
	TOTAL FED	2,920	26,780	2	0	3	7
	TOTAL	-	46,239	4	1	3	16
OD-38	BLM	1,240	4,832				
	TOTAL FED	1,240	4,832	1	1	1	1
	TOTAL	-	8,942	1	1	1	3
OD-49	BLM	800	2,925				
	TOTAL FED	800	2,925	1	0	1	1
	TOTAL	-	22,352	1	0	1	8
OD-50	BLM	240	8,733				
	TOTAL FED	240	8,733	2	1	2	4
	TOTAL	-	51,050	4	1	2	19
OD-53	NFS	38,440	77,822				
	TOTAL FED	38,440	77,822	8	7	12	30
	TOTAL	-	86,004	8	8	12	33
OD-54	BLM	2,640	4,904				
	TOTAL FED	2,640	4,904	2	0	1	2
	TOTAL	-	8,509	2	1	1	3
OD-55	BLM	200	1,446				
	TOTAL FED	200	1,446	0	0	0	1
	TOTAL	-	2,713	0	0	0	1
	PROV TOT FED	253,160	571,782	110	28	104	203
	PROVINCE TOTAL		828,068	125	39	111	306

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Table J.6. Acreage and owl numbers for designated conservation areas in the western Oregon Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-1	NFS	95,280	147,287				
	TOTAL FED	95,280	147,287	9	5	30	42
	TOTAL	-	148,299	9	5	30	42
OD-3	NFS	60,560	111,492				
	BLM	-	10				
	TOTAL FED	60,560	111,502	19	10	23	35
	TOTAL	-	111,716	19	10	23	35
OD-4	NFS	47,360	70,494				
	BLM	3,480	19,168				
	TOTAL FED	50,840	89,662	13	4	20	30
	TOTAL	-	98,610	13	4	20	32
OD-5	NFS	38,560	76,723				
	TOTAL FED	38,560	76,723	23	4	22	30
	TOTAL	-	80,982	23	4	22	31
OD-6	NFS	33,800	46,253				
	BLM	15,720	29,171				
	TOTAL FED	49,520	75,424	18	5	25	30
	TOTAL	-	81,251	18	5	25	32
OD-7	NFS	40,280	62,983				
	TOTAL FED	40,280	62,983	23	2	23	30
	TOTAL	-	67,248	23	2	23	31
OD-8	NFS	78,480	103,787				
	TOTAL FED	78,480	103,787	21	0	25	28
	TOTAL	-	103,792	21	0	25	28
OD-9	NFS	40,480	84,205				
	TOTAL FED	40,480	84,205	25	5	25	33
	TOTAL	-	84,370	25	5	25	33
OD-10	NFS	43,600	80,087				
	TOTAL FED	43,600	80,087	16	3	20	30
	TOTAL	-	80,087	16	3	20	30
OD-11	NFS	27,000	56,218				
	BLM	1,720	4,426				
	TOTAL FED	28,720	60,644	22	2	20	25
	TOTAL	-	65,444	22	2	20	26
OD-12	NFS	-	42				
	BLM	32,280	51,493				
	TOTAL FED	32,280	51,536	29	1	20	23
	TOTAL	-	89,741	29	3	20	33

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-13	NFS	19,760	90,009				
	TOTAL FED	19,760	90,009	27	1	25	35
	TOTAL	-	92,956	27	1	25	35
OD-14	NFS	-	78,758				
	BLM	200	263				
	TOTAL FED	200	79,021	29	1	25	33
	TOTAL	-	82,090	30	1	25	34
OD-15	NFS	4,560	87,560				
	TOTAL FED	4,560	87,560	16	2	18	25
	TOTAL	-	88,789	16	2	18	25
OD-17	NFS	4,840	10,879				
	BLM	15,120	24,206				
	TOTAL FED	19,960	35,085	24	5	13	20
	TOTAL	-	55,174	28	7	15	25
OD-18	NFS	27,665	63,137				
	NPS	510	872				
	TOTAL FED	28,175	64,009	20	2	18	25
	TOTAL	-	66,504	20	2	18	25
OD-19	NFS	39,265	80,559				
	TOTAL FED	39,365	80,559	14	2	14	23
	TOTAL	-	86,433	14	2	14	25
OD-39	BLM	920	6,929				
	TOTAL FED	920	6,929	2	0	1	1
	TOTAL	-	12,504	2	0	1	3
OD-40	BLM	8,440	29,854				
	TOTAL FED	8,440	29,854	6	1	5	10
	TOTAL	-	43,122	6	1	5	14
OD-56	BLM	360	1,752				
	TOTAL FED	360	1,752	0	0	0	1
	TOTAL	-	2,960	0	1	0	1
OD-57	BLM	440	1,602				
	TOTAL FED	440	1,602	0	1	0	1
	TOTAL	-	2,610	0	1	0	1
OD-58	BLM	560	1,444				
	TOTAL FED	560	1,444	1	0	1	1
	TOTAL	-	2,648	1	0	1	1
	PROV TOT FED	816,100	1,421,664	357	56	373	511
	PROVINCE TOTAL		1,547,330	362	61	375	542

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Table J.7. Acreage and owl numbers for designated conservation areas in the eastern Oregon Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-2	NFS	51,200	74,154				
	TOTAL FED	51,200	74,154	21	1	21	26
	TOTAL	-	74,558	21	1	21	26
OD-41	NFS	4,560	8,870				
	TOTAL FED	4,560	8,870	1	0	1	2
	TOTAL	-	9,855	1	0	1	2
OD-42	NFS	8,520	20,000				
	TOTAL FED	8,520	20,000	4	0	4	5
	TOTAL	-	20,000	4	0	4	5
OD-43	NFS	7,840	28,645				
	TOTAL FED	7,840	28,645	5	0	5	6
	TOTAL	-	29,367	5	0	5	6
OD-44	NFS	8,560	16,532				
	TOTAL FED	8,560	16,532	4	0	4	4
	TOTAL	-	16,532	4	0	4	4
OD-45	NFS	4,240	18,017				
	TOTAL FED	4,240	18,017	1	1	1	3
	TOTAL	-	18,256	1	1	1	3
OD-51	NFS	9,320	28,332				
	TOTAL FED	9,320	28,332	7	0	7	7
	TOTAL	-	28,601	7	0	7	7
OD-59	NFS	20,783	39,611				
	TOTAL FED	20,783	39,611	13	4	13	18
	TOTAL	-	41,858	13	4	13	18
OD-60	NFS	480	3,023				
	TOTAL FED	480	3,023	1	0	1	1
	TOTAL	-	3,023	1	0	1	1
OD-61	NFS	720	3,001				
	TOTAL FED	720	3,001	1	0	1	1
	TOTAL	-	3,001	1	0	1	1
OD-62	NFS	1,400	2,705				
	TOTAL FED	1,400	2,705	1	0	1	1
	TOTAL	-	2,705	1	0	1	1
OD-63	NFS	800	2,137				
	TOTAL FED	800	2,137	1	0	1	1
	TOTAL	-	3,013	1	0	1	1
OD-64	NFS	520	3,063				
	TOTAL FED	520	3,063	1	0	1	1
	TOTAL	-	3,063	1	0	1	1
OD-65	NFS	760	2,477				
	TOTAL FED	760	2,477	1	0	1	1
	TOTAL	-	3,028	1	0	1	1
	PROV TOT FED	119,703	250,567	62	6	62	77
	PROVINCE TOTAL		256,860	62	6	62	77

[a] The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Table J.8. Acreage and owl numbers for designated conservation areas in the Oregon Klamath province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-16	NFS	-	1,524				
	BLM	21,840	40,378				
	TOTAL FED	21,840	41,901	23	0	17	22
	TOTAL	-	85,379	23	1	17	30
OD-20[b]	NFS	18,800	60,104				
	BLM	600	931				
	TOTAL FED	19,400	61,035	15	3	14	23
	TOTAL	-	65,225	15	3	14	24
OD-21	NFS	3,160	7,826				
	BLM	25,200	49,277				
	TOTAL FED	28,360	57,103	13	3	11	20
	TOTAL	-	78,086	13	6	11	27
OD-22[b]	NFS	24,560	64,313				
	TOTAL FED	24,560	64,313	19	9	18	23
	TOTAL	-	67,047	19	9	18	23
OD-23	NFS	52,840	129,460				
	TOTAL FED	52,840	129,460	7	23	22	30
	TOTAL	-	130,447	7	23	22	30
OD-24	NFS	320	936				
	BLM	39,440	68,488				
	TOTAL FED	39,760	69,423	6	1	15	22
	TOTAL	-	74,771	6	1	15	24
OD-25	NFS	33,000	53,560				
	BLM	4,000	10,427				
	TOTAL FED	37,000	63,987	16	17	20	25
	TOTAL	-	71,133	17	17	20	27
OD-26	BLM	22,160	44,850				
	TOTAL FED	22,160	44,850	14	2	15	15
	TOTAL	-	86,684	21	4	18	30
OD-52	NFS	21,520	37,397				
	BLM	120	492				
	TOTAL FED	21,640	37,889	2	9	13	18
	TOTAL	-	40,654	2	9	13	19
CD-5	This DCA crosses state boundaries; data are illustrated in California Klamath province table (see Table J.10.						
	PROV TOT FED	267,560	569,961	115	67	145	198
	PROVINCE TOTAL	-	699,425	123	73	148	234

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.
[b] A portion of this DCA lies in the California Klamath province; data illustrated here are for the entire DCA.

Table J.9. Acreage and owl numbers for designated conservation areas in the California Coast province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Future Projected
CD-47	NFS	1,400	7,541				
	NPS	-	6,133				
	TOTAL FED	-	13,674	1	1	2	3
	TOTAL	-	32,388	1	1	4	7
CD-48	NPS	-	66,894				
	TOTAL FED	-	66,894	0	0	10	14
	TOTAL	-	80,250	0	0	13	17
CD-50	BLM	-	32,284				
	TOTAL FED	-	32,284	2	3	10	12
	TOTAL	-	38,455	2	3	10	13
CD-52	NPS	-	42,285				
	TOTAL FED	-	42,285	1	9	11	11
	TOTAL	-	73,644	1	14	22	22
CD-53	BLM	-	3,890				
	TOTAL FED	-	3,890	0	1	2	2
	TOTAL	-	8,306	0	2	3	4
CD-54	BLM	-	977				
	TOTAL FED	-	977	1	0	1	1
	TOTAL	-	1,558	1	0		1
CD-56	BLM	-	2,269				
	TOTAL FED	-	2,269	3	1	3	3
	TOTAL	-	2,269	3	1	3	3
CD-57	BLM	-	2,502				
	TOTAL FED	-	2,502	0	1	1	3
	TOTAL	-	6,574	0	1	1	4
CD-58[c]	BLM	-	1,145				
	TOTAL FED	-	1,145	0	0	1	2
	TOTAL	-	1,266	0	0	1	2
CD-59	BLM	-	2,759				
	TOTAL FED	-	2,759	0	0	3	4
	TOTAL	-	5,340	0	0	3	5
CD-60[c]	BLM	-	1,693				
	TOTAL FED	-	1,693	0	0	1	3
	TOTAL	-	2,899	0	0	1	3
CD-61[c]	BLM	-	2,701				
	TOTAL FED	-	2,701	1	0	1	3
	TOTAL	-	4,576	1	0	1	4
CD-62[c]	NFS	-	7				
	BLM	-	1,390				
	TOTAL FED	-	1,397	0	0	1	2
	TOTAL	-	2,676	0	0	1	2
CD-63[c]	BLM	-	2,299				
	TOTAL FED	-	2,299	0	2	1	3
	TOTAL	-	2,970	0	2	1	4

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-65	BLM	-	7,437				
	TOTAL FED	-	7,437	1	0	1	2
	TOTAL	-	10,676	1	0	1	2
CD-66	BLM	-	8,630				
	TOTAL FED	-	8,630	0	0	1	5
	TOTAL	-	12,907	0	0	1	7
CD-67	BLM	-	6,722				
	TOTAL FED	-	6,722	0	0	0	2
	TOTAL	-	8,090	0	0	0	2
CD-69[c]	BLM	-	2,255				
	TOTAL FED	-	2,255	0	0	1	2
	TOTAL	-	2,979	0	0	1	2
CD-70[c]	BLM	-	1,616				
	TOTAL FED	-	1,616	0	0	0	1
	TOTAL	-	2,555	0	0	0	2
CD-73	BLM	-	3,657				
	TOTAL FED	-	3,657	0	0	1	2
	TOTAL	-	4,650	0	0	1	2
CD-74	BLM	-	6,988				
	TOTAL FED	-	6,988	0	0	1	3
	TOTAL	-	7,715	0	0	1	3
CD-75	BLM	-	4,545				
	TOTAL FED	-	4,545	0	0	1	2
	TOTAL	-	6,953	0	0	1	2
CD-76[c]	BLM	-	1,069				
	TOTAL FED	-	1,069	0	0	1	1
	TOTAL	-	1,069	0	0	1	1
CD-77[c]	BLM	-	1,649				
	TOTAL FED	-	1,649	0	0	0	0
	TOTAL	-	1,865	0	0	0	0
CD-78[c]	BLM	-	895				
	TOTAL FED	-	895	0	0	1	1
	TOTAL	-	2,500	0	0	1	1
CD-80	BLM	-	3,222				
	TOTAL FED	-	3,222	0	0	1	2
	TOTAL	-	3,520	0	0	1	2
CD-201[c]	BLM	-	43				
	TOTAL FED	-	43	0	0	1	0
	TOTAL	-	43	0	0	1	0
CD-202[c]	BLM	-	426				
	TOTAL FED	-	426	0	0	1	1
	TOTAL	-	426	0	0	1	1
OD-22	This DCA crosses state boundaries; data are illustrated in Oregon Klamath province table.						
	PROV TOT FED	-	226,023	10	18	59	90
	PROVINCE TOTAL	-	329,122	10	24	76	118

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values noted as "-" indicate an unknown number.
[c]Recommended as DCAs rather than reserved pair areas because their contribution is needed for long-term management.

Table J.10. Acreage and owl numbers for designated conservation areas in the California Klamath province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-1	NFS	42,240	103,977				
	TOTAL FED	42,240	103,977	7	9	27	28
	TOTAL	-	104,956	7	9	27	28
CD-2	NFS	26,040	54,835				
	TOTAL FED	26,040	54,835	9	5	21	23
	TOTAL	-	55,596	9	5	21	23
CD-3	NFS	14,200	36,022				
	TOTAL FED	14,200	36,022	27	2	28	25
	TOTAL	-	38,032	27	2	28	25
CD-4	NFS	35,840	59,886				
	TOTAL FED	35,840	59,886	16	6	22	25
	TOTAL	-	62,989	16	6	22	25
CD-5[d]	NFS	14,960	82,659				
	TOTAL FED	14,960	82,659	8	4	25	29
	TOTAL	-	82,764	8	4	25	30
CD-6	NFS	13,000	47,510				
	TOTAL FED	13,000	47,510	10	7	20	22
	TOTAL	-	47,559	10	7	20	22
CD-7	NFS	1,840	13,541				
	TOTAL FED	1,840	13,541	7	0	6	8
	TOTAL	-	14,171	7	1	6	8
CD-8	NFS	71,280	140,117				
	TOTAL FED	71,280	140,117	23	5	42	44
	TOTAL	-	140,630	23	5	42	44
CD-9	NFS	2,120	6,281				
	TOTAL FED	2,120	6,281	1	2	2	2
	TOTAL	-	6,299	1	2	2	2
CD-10	NFS	17,520	53,349				
	TOTAL FED	17,520	53,349	13	4	21	23
	TOTAL	-	56,011	13	4	21	24
CD-11E	NFS	27,560	88,228				
	BLM	40	7,722				
	TOTAL FED	27,600	95,951	9	5	22	24
	TOTAL	-	97,567	9	5	23	25
CD-11W	NFS	44,320	95,195				
	TOTAL FED	44,320	95,195	12	6	26	28
	TOTAL	-	95,908	12	6	26	28
CD-12	NFS	17,400	51,922				
	TOTAL FED	17,400	51,922	8	5	21	23
	TOTAL	-	54,928	8	5	21	24
CD-13	NFS	24,080	39,761				
	TOTAL FED	24,080	39,761	7	3	16	20
	TOTAL	-	43,795	7	3	16	21

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Future Projected
CD-14	NFS	4,040	27,240				
	BLM	-	36				
	TOTAL FED	4,040	27,276	4	1	5	7
	TOTAL	-	30,042	4	1	5	7
CD-15	NFS	34,480	103,046				
	BLM	5,600	7,375				
	TOTAL FED	40,080	110,421	12	9	29	31
	TOTAL	-	112,694	12	9	29	33
CD-16	NFS	13,680	64,987				
	TOTAL FED	13,680	64,987	6	9	22	24
	TOTAL	-	66,371	6	9	22	24
CD-17	NFS	6,000	32,615				
	TOTAL FED	6,000	32,615	3	5	6	7
	TOTAL	-	33,597	3	5	6	7
CD-18	NFS	8,600	48,810				
	TOTAL FED	8,600	48,810	2	3	9	14
	TOTAL	-	50,221	2	3	9	14
CD-19	NFS	5,520	24,135				
	BLM	-	180				
	TOTAL FED	5,520	24,315	4	2	5	6
	TOTAL	-	27,563	4	2	5	8
CD-20	NFS	1,880	9,101				
	TOTAL FED	1,880	9,101	4	0	3	3
	TOTAL	-	9,758	4	0	4	4
CD-21	NFS	5,440	24,972				
	TOTAL FED	5,440	24,972	2	1	5	7
	TOTAL	-	25,465	2	1	5	7
CD-23	NFS	2,760	7,074				
	TOTAL FED	2,760	7,074	2	3	4	4
	TOTAL	-	7,145	2	3	4	4
CD-24	NFS	1,360	3,383				
	TOTAL FED	1,360	3,383	1	0	1	1
	TOTAL	-	3,383	1	0	1	1
CD-25	NFS	1,680	4,187				
	TOTAL FED	1,680	4,187	1	0	1	1
	TOTAL	-	4,218	1	0	1	1
CD-26	NFS	360	922				
	TOTAL FED	360	922	1	0	1	1
	TOTAL	-	1,716	1	0	1	1
CD-27	NFS	480	1,867				
	TOTAL FED	480	1,867	1	0	1	1
	TOTAL	-	2,262	1	0	1	1
CD-29	NFS	4,960	21,246				
	BLM	1,200	1,100				
	TOTAL FED	6,160	22,346	2	4	6	7
	TOTAL	-	26,613	2	4	6	8

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
CD-30	NFS	3,000	11,212				
	TOTAL FED	3,000	11,212	1	0	3	4
	TOTAL	-	13,187	1	0	3	5
CD-31	NFS	7,840	31,327				
	TOTAL FED	7,840	31,327	3	0	8	15
	TOTAL	-	40,191	3	1	9	17
CD-32	NFS	2,280	6,928				
	TOTAL FED	2,280	6,928	3	0	2	3
	TOTAL	-	9,811	4	0	3	4
CD-33	NFS	760	3,987				
	TOTAL FED	760	3,987	0	0	0	2
	TOTAL	-	4,133	0	0	0	2
CD-34	NFS	240	2,440				
	TOTAL FED	240	2,440	1	0	1	2
	TOTAL	-	3,138	1	0	1	2
OD-20	This DCA crosses state boundaries; data are illustrated in Oregon Klamath province table.						
	PROV TOT FED	457,800	1,319,755	210	100	411	464
	PROVINCE TOTAL	-	1,370,292	211	102	415	479

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.
[d]DCA crosses state boundaries; data reflect acreage and owls for entire DCA.

Table J.11. Acreage and owl numbers for designated conservation areas in the California Cascades province[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
CD-28	NFS	5,160	34,310				
	BLM	80	161				
	TOTAL FED	5,240	34,471	7	0	5	7
	TOTAL	-	41,356	7	0	5	7
CD-35	NFS	2,160	13,222				
	BLM	-	8				
	TOTAL FED	2,160	13,230	0	1	1	2
	TOTAL	-	13,992	0	1	1	2
CD-36	NFS	1040	2,096				
	TOTAL FED	1040	2,096	0	0	0	0
	TOTAL	-	2,133	0	0	1	1
CD-37	NFS	240	5,647				
	TOTAL FED	240	5,647	1	0	1	2
	TOTAL	-	5,710	1	0	1	2
CD-38	NFS	2,560	9,556				
	TOTAL FED	2,560	9,556	0	1	1	3
	TOTAL	-	9,982	0	1	1	4

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-39	NFS	880	3,674				
	TOTAL FED	880	3,674	0	0	0	0
	TOTAL	-	3,722	0	0	0	0
CD-40	NFS	640	2,202				
	TOTAL FED	640	2,202	1	0	1	1
	TOTAL	-	2,419	1	0	1	1
CD-41	NFS	1,200	3,117				
	TOTAL FED	1,200	3,117	1	0	1	1
	TOTAL	-	3,600	1	0	1	1
CD-42	NFS	22,920	64,663				
	TOTAL FED	22,920	64,663	5	4	10	12
	TOTAL	-	70,985	5	5	12	15
CD-43	NFS	1,120	13,590				
	TOTAL FED	1,120	13,590	2	2	3	4
	TOTAL	-	14,442	2	2	3	4
CD-44	NFS	2,920	10,430				
	TOTAL FED	2,920	10,430	2	0	2	3
	TOTAL	-	11,095	2	0	2	3
CD-45	NFS	3,840	21,327				
	TOTAL FED	3,840	21,327	1	2	4	5
	TOTAL	-	38,644	1	2	4	6
CD-101	NFS	-	1,788				
	TOTAL FED	-	1,788	0	0	1	1
	TOTAL	-	1,913	0	0	1	1
CD-102	NFS	400	2,831				
	TOTAL FED	400	2,831	1	1	1	1
	TOTAL	-	3,032	1	1	1	1
CD-103	NFS	40	2,656				
	TOTAL FED	40	2,656	0	0	1	1
	TOTAL	-	2,699	0	0	1	1
CD-104	NFS	440	1,350				
	TOTAL FED	440	1,350	0	1	1	1
	TOTAL	-	2,881	0	1	1	1
CD-105	NFS	240	1,117				
	TOTAL FED	240	1,117	0	1	1	1
	TOTAL	-	1,267	0	1	1	1
CD-106	NFS	800	1,994				
	TOTAL FED	800	1,994	0	1	1	1
	TOTAL	-	1,994	0	1		
CD-107	NFS	2,240	2,778				
	TOTAL FED	2,240	2,778	1	0	1	1
	TOTAL	-	8,880	1	0	1	1
CD-108	NFS	240	2,489				
	TOTAL FED	240	2,489	1	0	1	1
	TOTAL	-	2,560	1	0	1	1
CD-109	NFS	200	1,689				
	TOTAL FED	200	1,689	0	0	0	0
	TOTAL	-	1,910	0	1	1	1

continues—

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DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-110	NFS	640	2,880				
	TOTAL FED	640	2,880	0	1	1	1
	TOTAL	-	2,881	0	1	1	1
CD-111	NFS	320	2,587				
	TOTAL FED	320	2,587	0	0	1	1
	TOTAL	-	2,881	0	0	1	1
	PROV TOT FED	50,320	208,162	23	15	39	50
	PROVINCE TOTAL	-	244,978	23	17	43	57

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Literature Cited

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. Report of the Interagency Scientific Committee to address the conservation of the northern spotted owl. U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, and National Park Service, Portland, Oregon, U.S. Government Printing Office 1990: 791-171/20026.

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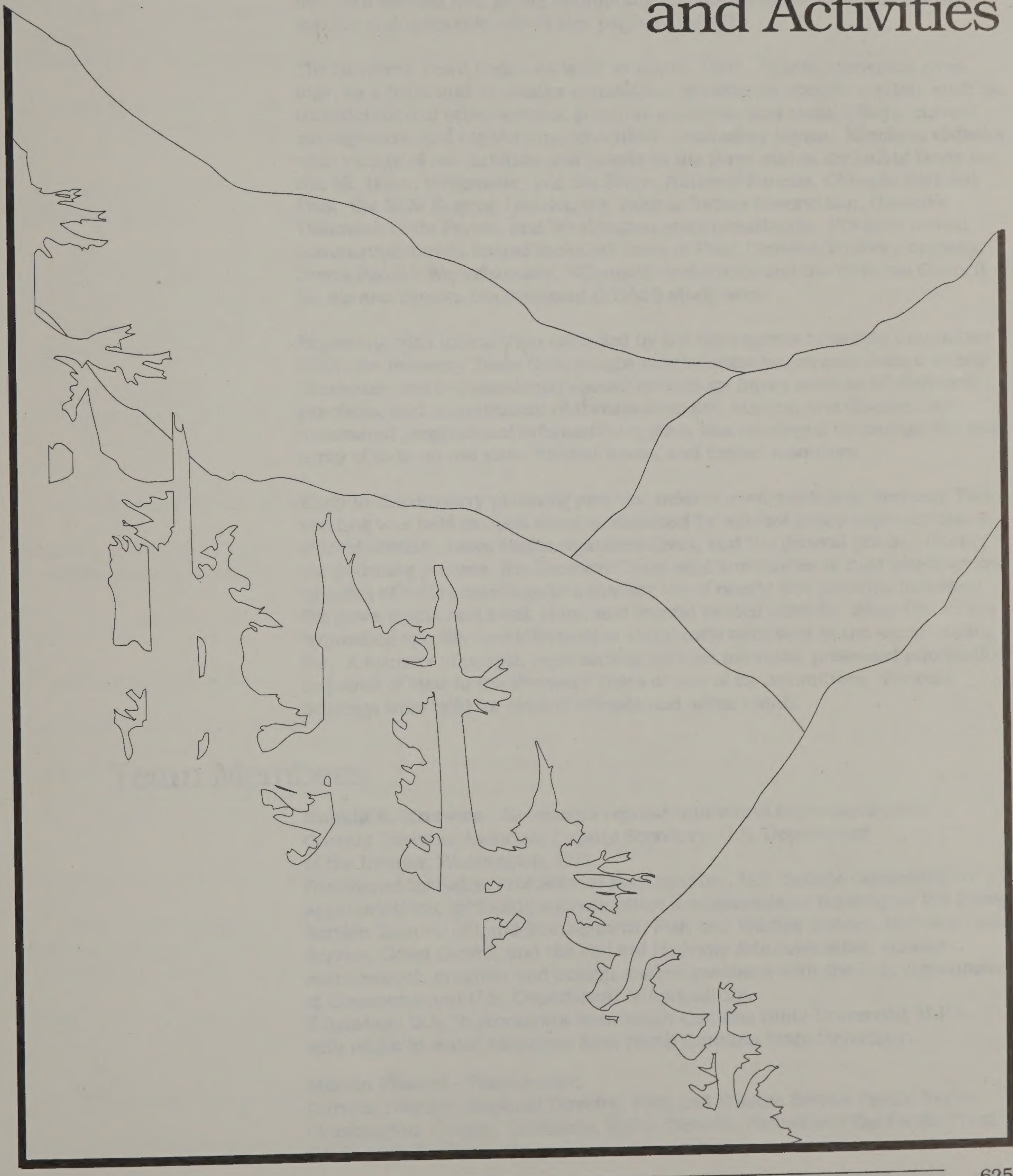
USDA, Forest Service. 1992. Final environmental impact statement on management for northern spotted owls in national forests. USDA Forest Service, Pacific Northwest Region. Portland, Oregon.

Appendix K

Recovery Team Members and Activities



The Recovery Team

The Recovery Team is made up of 18 members appointed by Secretary of the Interior Manuel Lujan Jr. The members include biologists, ecologists, foresters, economists, federal forest and wildlife managers, and representatives of the governors of the three affected states.

Secretary Lujan directed the Recovery Team to develop a recovery plan for the northern spotted owl, giving appropriate consideration to the needs of other species and economic effects (see pages 639-641).

The Recovery Team began its work in March 1991. It held numerous meetings, as a team and in smaller committees working on specific matters such as consideration of other species, potential economic and social effects, current management and regulations, silviculture, and other topics. Members visited a wide variety of owl habitats and forests in the three states, including lands in the Mt. Hood, Willamette, and Six Rivers National Forests, Olympic National Park, the BLM Eugene District, the Yakima Indian Reservation, Oregon's Tillamook State Forest, and Washington state forestlands. Privately owned commercial forests toured included those of Fruit Growers Timber Company, Sierra Pacific, Weyerhaeuser, Willamette Industries and the National Council for Air and Stream Improvement (NCASI) study area.

Beginning with information compiled by the Interagency Scientific Committee (ISC), the Recovery Team then sought new information on owls from a variety of sources and commissioned special reviews on topics such as silvicultural practices, and management of threats from fire, insects, and disease. An automated geographical information system was developed to manage the great array of data on owl sites, habitat areas, and timber resources.

Early in the recovery planning process, most of each week-long Recovery Team meeting was held in open session, attended by interest group representatives, elected officials, news media representatives, and the general public. During the planning process, the Recovery Team sent summaries of past meetings and agendas of future meetings to a mailing list of nearly 400 persons, including the news media and local, state, and federal elected officials. Also, two letters requesting specific new information about owls were sent to the same mailing list. A number of people, representing various interests, presented information or points of view to the Recovery Team or one of its committees. Periodic briefings were held for elected officials and agency staff.

Team Members

Donald R. Knowles - *Secretary's representative and team coordinator.*
Current Position: Associate Deputy Secretary, U.S. Department of the Interior, Washington, D.C.
Experience Includes: Professional staff member, U.S. Senate Committee on Appropriations, including subcommittee assignments on funding for the Forest Service, Bureau of Land Management, Fish and Wildlife Service, National Park Service, Coast Guard, and the Federal Highway Administration; various management, program and budget analyst positions with the U.S. Department of Commerce and U.S. Department of Agriculture.
Education: B.A. in economics from North Carolina State University; M.P.A. with major in water resources from North Carolina State University.

Marvin Plenert - *Team leader.*
Current Position: Regional Director, Fish and Wildlife Service Pacific Region (Washington, Oregon, California, Idaho, Nevada, Hawaii and the Pacific Trust Territories), Portland, Oregon.

Experience Includes: Assistant Director, Refuges and Wildlife, FWS national headquarters; Deputy Assistant Regional Director, Refuges and Wildlife, FWS Rocky Mountain region; refuge supervisor for operations, FWS Alaska region.
Education: B.S. and M.S. in wildlife management from Kansas State University.

Jonathan Bart - *Chairman.*
Current position: Assistant Leader of the Ohio Cooperative Fish and Wildlife Research Unit; Associate professor in the Department of Zoology at Ohio State University, Columbus, Ohio.
Experience includes: teaching graduate seminars and courses in wildlife biology, biometry and behavioral ecology; publications in the areas of survey design and evaluation, survival analysis, quantitative analysis, and behavioral ecology.
Education: B.S, in biology from Syracuse University, M.S. in ecology from Cornell University, Ph.D. in wildlife biology from Cornell University.

Robert G. Anthony
Current position: Assistant Unit Leader and Professor of Wildlife Ecology, Oregon Cooperative Wildlife Research Unit, Oregon State University, Corvallis, Oregon.
Experience includes: Teaching mammalogy, wildlife natural history, and wildlife biometrics; researching, and directing graduate students in research in the areas of wildlife ecology, dynamics of wildlife populations, and application of quantitative procedures to ecological concepts; Assistant and Associate Professor of Wildlife Ecology, Pennsylvania State University; 15 publications within the last 5 years.
Education: B.S. in biology from Fort Hays Kansas State College; M.S. in Wildlife Biology from Washington State University; Ph.D. in zoology from University of Arizona.

Melvin Berg
Current position: Chief, Division of Forestry, U.S. Bureau of Land Management, Washington, D.C.
Experience includes: BLM district manager, Roseburg, Oregon; BLM associate district manager; area manager, natural resource specialist, realty specialist, access specialist, and forester.
Education: B.S. in forest management from Iowa State University.

John H. Beuter
Current position: Deputy Assistant Secretary of Agriculture for Natural Resources and Environment, Washington, D.C.
Experience includes: Consulting Forester with Mason, Bruce and Girard, Inc., Portland, Oregon; professor and department head of Forest Management at Oregon State University; director of Oregon State University research forests.
Education: B.S. in forestry, M.S. in forest economics from Michigan State University, Ph.D. in forestry and economics from Iowa State University.

Wayne Elmore
Current position: U.S. Bureau of Land Management State Riparian Specialist for Oregon and Washington, Prineville, Oregon.
Experience includes: BLM resource area forester, and BLM district wildlife biologist in Spokane, Washington; BLM district wildlife and fisheries biologist in Prineville, Oregon; approximately 20 publications on riparian ecosystem function and management.
Education: B.S. in forest management from Oklahoma State University, post-graduate studies in fisheries and wildlife management.

John Fay
Current position: General Biologist, Division of Endangered Species, U.S. Fish and Wildlife Service, Washington D.C.
Experience includes: Botanist, Division of Endangered Species, FWS; Assistant

Chief, Branch of Biological Support, Office of Endangered Species, FWS; Associate Editor, Flora North America; Botanist, Pacific Tropical Botanical Garden; former FWS.representative on Species Survival Commission, I.U.C.N.; numerous scientific and Federal Register publications.
Education: B.S. in biology from Fordham College; Ph.D. in biology from City University of New York.

R. J. Gutiérrez
Current position: Professor, Department of Wildlife, Humboldt State University, Arcata, California. Current major studies ongoing in habitat, dispersal, genetics, and population dynamics of the spotted owl.
Experience includes: Chairman of Wildlife, Humboldt State University; assistant professor in the Department of Natural Resources at Cornell University; more than 70 wildlife consulting projects for universities, associations, and corporations; more than 30 peer-reviewed publications on avian ecology.
Education: B.S. in wildlife biology from Colorado State University; M.S. in biology from University of New Mexico; Ph.D. in zoology from University of California, Berkeley.

H. Theodore Heintz, Jr.
Current position: Assistant Director for Economic Analysis, Office of Policy Analysis, U.S. Department of the Interior, Washington, D.C.
Experience includes: Staff Director of the President's Task Force on Outer Continental Shelf Leasing and Development; Research Director, Commission of Fair Market Value Policy for Federal Coal Leasing; Director of Economics and Systems Analysis, Earth Satellite Corporation, Washington, D.C.
Education: B.E.E. in electrical engineering from Cornell University; M.P.A. in public affairs from the Woodrow Wilson School of Public and International Affairs at Princeton University.

Richard S. Holthausen
Current position: National Wildlife Ecologist, U.S. Forest Service, Logan, Utah.
Experience includes: Regional Wildlife Ecologist, U.S. Forest Service Pacific Northwest Region; Assistant Wildlife Ecologist, National Fish and Wildlife Ecology Unit, F.S.; forest planner, Bighorn National Forest; forest planning biologist and range conservationist, Bighorn National Forest; range scientist, Peter Kiewit Sons Mining, Sheridan, Wyoming; various teaching and course design work in forest management, wildlife and fish ecology.
Education: B.S. in ecology and mathematics from Cornell University; M.S. in ecology from Utah State University.

Kenneth Lathrop
Current position: Supervisory Forester, Forest Products and Sale Administration, U.S. Bureau of Indian Affairs, Portland, Oregon.
Experience includes: Assistant Forester - Timber Sales, Portland Area Bureau of Indian Affairs; District Ranger and Timber Sale Officer, White Swan Ranger Station, Yakima Indian Reservation.
Education: B.S. in forestry from Michigan Technological University; post graduate work in forestry, wildlife, Indian culture, and public administration at Oregon State University, Washington State University, University of Washington, Central Washington College, and Lewis and Clark College.

Kent Mays
Current position: Program Manager for Spotted Owl Research, Development and Application program involving 24 national forests and two forest and range experiment stations, Portland, Oregon.
Experience includes: 34 years with the U.S. Forest Service in various line and staff positions, including District Ranger and Forest Supervisor, on seven national forests in four states; worked in various positions in the U.S. Forest Service National Headquarters in Washington D.C. in recreation, planning, and legislative affairs; and the President's Commission on American Outdoors.

Education: B.S. in forestry from Oregon State University, studies in Public Administration at American University, awarded an American Political Science Association Congressional Fellowship.

Richard Nafziger - *Representing the Governor of the State of Washington.*
Current position: Special Assistant to the Governor for Timber Policy and Rural Development; Coordinator of Interagency Task Force on Timber Community Development, Olympia, Washington.
Experience includes: Member of Governor's Economic Recovery Coordination Board; senior policy analyst for Economic Development and Labor, Office of Financial Management.
Education: B.A. in religion from Macalester College, St. Paul, Minnesota; M.S. in economics, New School for Social Research, New York, New York.

Martha Pagel - *Representing the Governor of the State of Oregon.*
Current position: Oregon Governor's Senior Policy Advisor on Natural Resources, Salem, Oregon.
Experience includes: Director, and Deputy Director, Oregon Division of State Lands; Assistant Attorney General, General Counsel Division, Oregon Department of Justice, providing general legal advice to various natural resource agencies.
Education: B.A., in Journalism, San Diego State University; J.D., Willamette University College of Law.

Christine Sproul - *Representing the Governor of the State of California.*
Current position: Assistant Secretary, Legal Affairs, The Resources Agency of California, Sacramento, California.
Experience includes: Staff Counsel, Office of the General Counsel, California Air Resources Board; Staff Counsel, Office of the Chief Counsel, State Water Resources Control Board.
Education: B.A., in international relations from the University of California, Davis; J.D. from Martin Luther King Jr. Law School, University of California, Davis, California.

Edward E. Starkey
Current position: Research Biologist and Terrestrial Ecology Program Leader, National Park Service Cooperative Park Studies Unit, Oregon State University; Professor of terrestrial ecology, Departments of Forest Resources, and Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.
Experience includes: Chief scientist and wildlife ecologist for the National Park Service Denver Service Center; research and teaching assistant in zoology and biology at Washington State University; more than 30 publications (and six theses supervised) since 1980, mostly concerning deer and elk in old-growth forests, fire ecology, and nutritional ecology.
Education: B.S. in biology from Bemidji State University; M.A. in biology from St. Cloud State University; Ph.D. in zoology from Washington State University.

John C. Tappeiner
Current position: Professor of Forestry at Oregon State University, Corvallis, Oregon, teaching silviculture and forest ecology, research in shrub and hardwood ecology and vegetation management and forest stand growth.
Experience includes: Lecturer in forestry, University of California, Berkeley; Regional Silviculturist for U.S. Forest Service Region 5 (17 national forests in California); international forestry consulting; associate professor University of Minnesota Cloquet Forest Research Center; numerous peer-reviewed papers.
Education: B.S., M.S., and Ph.D. in forestry (specializing in forest ecology and silviculture) all from the University of California, Berkeley.

Table K.1. Committee Membership.

Committee	Leader	Members	(Support)
Spotted Owl	Holthausen	Starkey	(Bruce)
	Gutiérrez	Berg	(Hays)
		Mays	(Gould)
		Lathrop	(Ogden)
		Anthony	
Forest Ecology	Tappeiner	Beuter	(Hanus)
		Berg	(Raettig)
		Mays	(Tuazon)
		Lathrop	
Economic	Heintz	Fay	(Raettig)
		Nafziger	(Tuazon)
Other Species	Anthony	Starkey	(Bruce)
		Elmore	
		Fay	
Planning	Elmore	Berg	(Hanus)
	Nafziger	Mays	(Tuazon)
		Lathrop	(Finfer)
		Beuter	(Partridge)
		Pagel	(Elliott)
		Sproul	(Ogden)
Executive	Bart	Holthausen	(Finfer)
		Fay	
		Anthony	
		Nafziger	
		Elmore	
		Gutiérrez	
		Tappeiner	
		Heintz	

Team Support

Charles Bruce, Oregon Department of Fish and Wildlife
Philip Carroll, U.S. Fish and Wildlife Service
Susan Earnst, Department of Zoology, Ohio State University
Catherine Elliott, Washington Governor's Timber Team
Lawrence Finfer, U.S. Department of the Interior
Gordon Gould, California Department of Fish and Game
Ann Hanus, Oregon Department of Forestry
David Hays, Washington Department of Wildlife
David Johnson, Oregon Department of Fish and Wildlife
Linda Kucera, U.S. Forest Service
Cay Ogden, U.S. Bureau of Indian Affairs
Josefa O'Malley, U.S. Department of the Interior, Office of the Solicitor
Craig Partridge, Washington Department of Natural Resources
Nancy Pollot, U.S. Fish and Wildlife Service
Fred Seavey, U.S. Fish and Wildlife Service
Raul Tuazon, California Department of Forestry and Fire Protection

Table K.2. Chronology of team activities.

Date	Event	Subject
3-05-91	Recovery Team meeting Portland, Oregon	Discussion of Recovery Team structure, schedule and reporting dates, and logistics.
3-27 thru 3-29-91	Recovery Team meeting Portland, Oregon	Overview of Endangered Species Act and other applicable laws, introduction to recovery planning, briefings on owl biology, silviculture, and forest ecology.
4-05-91	Other Species Subgroup meeting Portland, Oregon	Discussions of species and communities likely to benefit from the recovery plan, strategy for incorporating these into development of the plan, and benefits of reserves versus corridors between reserves.
4-15 and 4-16-91	Spotted Owl Subgroup meeting Portland, Oregon	Discussions of peer review, data bases available to Recovery Team, criteria for owl range map, need for updating information on defining suitable habitat.
4-22 and 4-23-91	Recovery Team meeting Portland, Oregon	Committee reports. Discussion of ISC Appendices F, G, H, O, and P. Discussion of owl range. Executive Session: budgetary issues, travel vouchers, staff needs.
4-24-91	Recovery Team field trip	Mt. Hood National Forest with Estacada Ranger District Forest Service personnel.
4-25-91	Economic Subgroup meeting Salem, Oregon	Met with experts from State of Oregon agencies and universities.
5-03-91	Other Species Subgroup meeting Portland, Oregon	Discussion of old-growth ecosystem concerns, GIS mapping strategies, importance of corridors.
5-9-91	Economic Subgroup meeting University of California, Berkeley, California.	Met with experts from State of California agencies, universities, and consulting groups.
5-13-91	Other Species Subgroup meeting Corvallis, Oregon	Final assignments made and deadlines agreed to.
5-14 thru 5-16-91	Recovery Team meeting Lake Crescent, Washington (Olympic Peninsula)	Committee reports. Discussion of ISC Appendices L, R, S, and T; economic impacts of recovery; critical habitat; proposed other recovery goals; recovery options previously identified.
5-17-91	Recovery Team field trip	Lake Crescent, Washington (Olympic Peninsula).
5-20-91	Economic Subgroup meeting University of Washington, Seattle, Washington.	Met with experts from State of Washington agencies and universities.

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5-24-91	Other Species Subgroup meeting Olympia, Washington	Meeting at Forest Service Pacific Northwest Research Station to discuss species that may be influenced by the recovery plan.
5-29-91	Other Species Subgroup meeting Portland, Oregon	Meeting with J. Sedell and G. Reeves (Forest Service) to discuss native fish that might be benefitted by the plan.
5-29 thru 5-30-91	Spotted Owl Subgroup meeting Portland, Oregon	Update on range mapping, status and threats section, descriptions of suitable habitat and mapping of suitable spotted owl habitat, summary of vegetation data bases, discussion of roles of silvicultural prescriptions, report on goals and objectives.
6-06 and 6-07-91	Other Species Subgroup meeting Portland, Oregon	Meeting with California Departments of Fish and Game, Forestry to discuss lists of sensitive species.
6-12-91	Economic Subgroup meeting Portland, Oregon	Evaluation of economic outline.
6-12 thru 6-14-91	Spotted Owl Subgroup meeting Portland, Oregon	Discussion of final review of goals, review of status and criteria for range mapping; review of status and threats section; review of suitable habitat definitions.
6-17 and 6-18-91	Recovery Team field trip California	Visit to Sierra Pacific Industries forestland, Sacramento Canyon and Deadwood, Fruitgrowers Supply Company forestland, Willow Creek study area, and Simpson timberland.
6-19 thru 6-21-91	Recovery Team meeting Arcata, California	Committee reports, discussion of revised recovery goals, plan organization, process for identifying options and establishment of milestones, presentation of options being considered by BLM.
6-26 thru 6-28-91	Spotted Owl Subgroup meeting Portland, Oregon	Discussion of suitable habitat definition, GIS, range mapping, delisting criteria, process for evaluating option. Presentation by J. Agee on fire and windthrow.
7-02-91	Other Species Subgroup meeting Oregon State University Corvallis, Oregon	Review of other species to be considered, principles and objectives, and outline for appendices.
7-03-91	Planning Committee meeting Portland, Oregon	Discussion of implementation on federal and nonfederal lands, incentives for private land wildlife protection.
7-10 thru 7-13-91	Spotted Owl Subgroup meeting Portland, Oregon	Revision of significant threats document, options for recovery, delisting criteria, range mapping.
7-10-91	Planning Committee meeting Portland, Oregon	Review of documents on plan implementation, problems and issues federal and nonfederal lands.

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7-16 thru 7-19-91	Recovery Team meeting Springfield, Oregon	Committee reports. Discussion of recovery goals and delisting criteria, options for achieving recovery.
7-17-91	Planning Committee meeting Portland, Oregon	Definition of goals. Division of assignments.
7-18-91	Recovery Team field trip	BLM Coast Range Resource Area Springfield, Oregon.
7-29 thru 7-31-91	Spotted Owl Subgroup meeting Portland, Oregon	Review of states' progress on significant threats document, range maps, report on McKelvey model, options for recovery, and delisting criteria. Presentation by J. Thomas on old-growth preserve options presented to Congress.
8-08 and 8-09-91	Recovery Team workshop Portland, Oregon	Other species and ecosystem issues. Presentations on marbled murrelets, riparian ecosystems, sensitive streams and stocks of native fish, amphibians, spotted owl prey, goshawks, bald eagles, marten and fisher, plants associated with older forest ecosystems, and ecological corridors.
8-14 thru 8-16-91	Spotted Owl Subgroup meeting Portland, Oregon	Review of range map, map of physiographic provinces, delisting criteria, evaluation process and data needed.
8-19 thru 8-22-91	Recovery Team meeting and field trip Portland, Oregon	Committee reports. Presentation on stand simulators and Douglas County project. Discussion of evaluation procedures, old-growth preserves, and critical habitat.
8-21-91	Recovery Team field trip	Yakima Indian Reservation Forest, Yakima, Washington.
8-22-91	Planning Committee meeting Portland, Oregon	Discussion of items needed in recovery plan from planning group and division of assignments.
9-04 thru 9-05-91	Spotted Owl Subgroup meeting Portland, Oregon	Completion of map work. Review status and threats by province, contributions from private lands.
9-06-91	Other Species Subgroup meeting Oregon State University Corvallis, Oregon	Discussion of priorities for marbled murrelets, native fish and wolves, grizzly bears, and goshawks. Role of ecological corridors and coarse woody debris.
9-09 thru 9-13-91	Spotted Owl Subgroup meeting Portland, Oregon	Completion of options for federal lands. Discussion of working groups for each state to finalize options.
9-11-91	Planning Committee meeting Portland, Oregon	Briefing on state and private lands recovery options, plan implementation, HCPs, private land incentives, and analysis of harvest impacts.

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9-16 thru 9-20-91	Spotted Owl Subgroup meeting Portland, Oregon	Review salvage report, data layers in GIS and salvage and silvicultural activities. Discuss options for nonfederal lands. Presentation of industry proposal for recovery plan.
9-19-91	Planning Committee meeting Portland, Oregon	Discussion of institutional mechanisms for nonfederal lands, principles of implementation, individual management plans for DCAs, and critical habitat. Presentation on Bull Run watershed.
9-23 thru 9-27-91	Recovery Team meeting Portland, Oregon	Committee reports. Presentation on Bull Run watershed. Discussion of ecological significance of coarse woody debris; effects of fire, wind, insects, and disease; silvicultural methods for improving and retaining owl habitat inside and outside DCAs.
9-26-91	Spotted Owl Subgroup meeting Portland, Oregon	Meeting with Forest Ecology Committee to discuss management of catastrophic risk in DCAs.
9-27-91	Planning Committee meeting Portland, Oregon	Discussion of process for evaluating proposals, writing tasks, four-step process for integration, development of landscape alternative, oversight mechanism, and critical habitat.
10-04-91	Planning Committee meeting Portland, Oregon	State and private participation, critical habitat, implementation issues.
10-11-91	Planning Committee meeting Portland, Oregon	Conference call to discuss take, HCP, section 4(d) rule.
10-15 and 10-16-91	Planning Committee meeting Portland, Oregon	Discussion of critical habitat, take, HCP, section 4(d) rule. Report on "silviculture, salvage and catastrophic risk management in DCAs." Review of draft material on implementation on state and private lands, coordination and oversight mechanisms, current management.
10-17 and 10-18-91	Recovery Team meeting Portland, Oregon	Committee reports. Progress report on chapters. Discussion of recommendations for critical habitat, DCA network matrix management, management on east side forests, development of research and monitoring program, and demographic analysis.
10-29 thru 11-01-91	Recovery Team meeting Portland, Oregon	Mapping designated conservation areas with participation of representatives from the national forests and BLM districts.
11-04 thru 11-08-91	Recovery Team meeting Portland, Oregon	Committee reports. Discussion of management guidelines for DCAs and matrix.
11-05-91	Planning Committee meeting Portland, Oregon	Discussion of state proposals and current management.

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12-03 thru 12-06-91	Recovery Team meeting Portland, Oregon	Committee reports. Discussion of critical habitat, Washington D.C. review, chapters I, II, and III.
1-14 and 1-15-92	Recovery Team meeting Portland, Oregon	Report on Washington D.C. review of draft recovery plan, results from peer review, Appendices A, B, H, and I, proposed revisions to plan, and Secretary's directive to the Recovery Team.

Technical Reports Prepared for the Recovery Team

Benson, G. 1991. Summary of northern spotted owl nest site information in eastern Washington. Unpublished manuscript. Spotted owl RD&A (research, development, and applications) Program, Pacific Northwest Experiment Station, U.S. Forest Service, Portland, Oregon.

Benson, G. 1991. Characterization of spotted owl habitat: east slope of the Washington and Oregon Cascades (Draft). Unpublished manuscript. Spotted owl RD&A (research, development and applications) Program, Pacific Northwest Experiment Station, U.S. Forest Service, Portland, Oregon.

Birch, K. 1991. Silviculture systems for Douglas-fir. Unpublished report submitted to the Northern Spotted Owl Recovery Team.

Frest, T.J. and E.J. Johannes. 1991. Present and potential candidate molluscs occurring within the range of the northern spotted owl. Unpublished manuscript. Deixis Consultants. Seattle, Washington.

Grenier, J. 1991. Review of information on structure of old-growth stands and old-growth stands used by spotted owls in western Oregon and Washington. Unpublished manuscript submitted to the Northern Spotted Owl Recovery Team.

Lamberson, R.H. and S. Brooks. 1991. An xxamination of the high density of northern spotted owls in nmorthwestern California. Unpublished manuscript. Department of Mathematics and Program in Environmental Systems, Humboldt State University, Arcata, California.

McComb, W.C. 1991. The role of dead wood in habitat of spotted owl prey and other old forest vertebrates. Unpublished manuscript. Department of Forest Science, Oregon State University, Corvallis, Oregon.

Morrell, J.J. 1991. Role of fungi in coarse woody debris. Unpublished manuscript. Department of Forest Products, Oregon State University, Corvallis, Oregon.

Oliver, C. 1991. northern spotted owl habitat in previously managed forests in western and eastern Washington with and without further management. Unpublished manuscript. College of Forestry, University of Washington, Seattle, Washington.

Perry, D. 1991. The ecology of coarse woody debris in Pacific Northwest forests: overview, and the role of down logs in ecosystem processes. Department of Forest Science, Oregon State University, Corvallis, Oregon.

Stere, D.H. 1991. A discussion of forest stand simulators. Unpublished manuscript. Oregon Department of Forestry, Salem, Oregon.

Weatherspoon, P. and M. Ritchie. 1991. Silvicultural prescriptions for mixed conifer stands in northern California. Unpublished report submitted to the Northern Spotted Owl Recovery Team.

THE SECRETARY OF THE INTERIOR

WASHINGTON

February 5, 1991

Memorandum

To: Donald R. Knowles, Secretary's Representative and Recovery Team Coordinator
Marvin L. Plenert, Recovery Team Leader

From: The Secretary

Subject: Directive to Northern Spotted Owl Recovery Team

Pursuant to Section 4(f) of the Endangered Species Act, the goal of the recovery team effort is to develop a plan that will lead to the conservation and survival of the northern spotted owl. The northern spotted owl recovery plan will serve as a guide to future Federal, State and private activities affecting the owl and will be designed to bring the owl to the point at which it will no longer need the protection of the Endangered Species Act (Act).

The requirements for recovery plans are specified in the Act:

(i) a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species;

(ii) objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this section, that the species be removed from the list; and

(iii) estimates of the time and cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal.

The planning process also must ensure that all available scientific information is considered prior to the plan's completion. To the extent consistent with its legal mandate, the plan also should address concerns such as: potential community and region-wide economic and social impacts; fiscal implications at the local, State and Federal levels; compatibility with other legal mandates; effects on other threatened and endangered species and those species which might be listed in the future; and broader ecosystem-related considerations.

The recovery team has considerable latitude in which to carry out its task. The Act specifies no road map to recovery, nor does it

mandate the achievement of recovery within a particular time frame. Accordingly, recovery plans for other listed species have employed a wide variety of management approaches. I encourage the team to exercise the full range of its creative abilities in assessing options for the recovery of the northern spotted owl. The recovery plan, however, must have a sound and credible scientific basis, so that we can be confident that its implementation will meet the Act's requirements.

In addition to the issues noted above, there are several specific concerns that I request the team to consider in the plan's development process:

- **Interagency Scientific Committee Conservation Strategy:** The ISC conducted a comprehensive review of science on the northern spotted owl. The team should consider that science and incorporate it, as appropriate, with all new scientific data, in the recovery planning effort.

- **Risk Analysis:** The team should assess the feasibility of developing recovery options that address the degree of risk (and associated uncertainty) to the owl, other species, other environmental values, and economic concerns.

- **Subdivided Plans/Recovery Targets:** The team should determine the feasibility of dividing the plan into sections that address individual States or physiographic provinces. As part of this effort, the team should evaluate the propriety of setting recovery targets for such locales. In so doing, options such as determining desired population ranges rather than fixed number targets, and varying ranges or targets by date and locale should be assessed. It is important to note, however, that any plan that includes subdivisions must also be assessed as a whole in terms of its ability to meet the Act's mandates and other concerns related to the plan effort.

- **Potential Impact of State and Private Actions:** Policies carried out by States, other political subdivisions, and private landowners may significantly affect the range of recovery plan options available for Federal lands. Potential actions by these non-Federal parties which could contribute to owl recovery should be assessed in terms of feasibility and implementation requirements. As appropriate, the team should incorporate assumptions concerning non-Federal actions into plan options as they are developed.

- **Population Genetics and Adaptability:** The team should assess the feasibility of considering population genetics and adaptability assumptions in developing the plan. These may yield insights concerning the ability of owls to survive in various habitats.

- o **Ecosystem Issues:** There are other forest ecosystem species that may be candidates for listing under the Act which may benefit from any recovery plan for the owl. To the extent possible, the team should assess the relative benefits to these species from the implementation of various recovery options.

- o **Forest Management Practices:** The team should assess the potential impacts of alternative forest and land management practices in determining potential recovery plan scenarios, including the plan's relationship to other land use planning exercises.

- o **Cost to the Public:** Potential plan options should document the direct and indirect public costs of implementation.

The recovery team leader will be responsible for managing the team, including the preparation of its work plan, staffing and administration, drafting the recovery plan, and assuring public comment. The recovery team coordinator will serve as the Secretary's representative and will be responsible for providing initial and ongoing policy guidance, through direct and frequent consultation with the team leader and with other members, as appropriate.

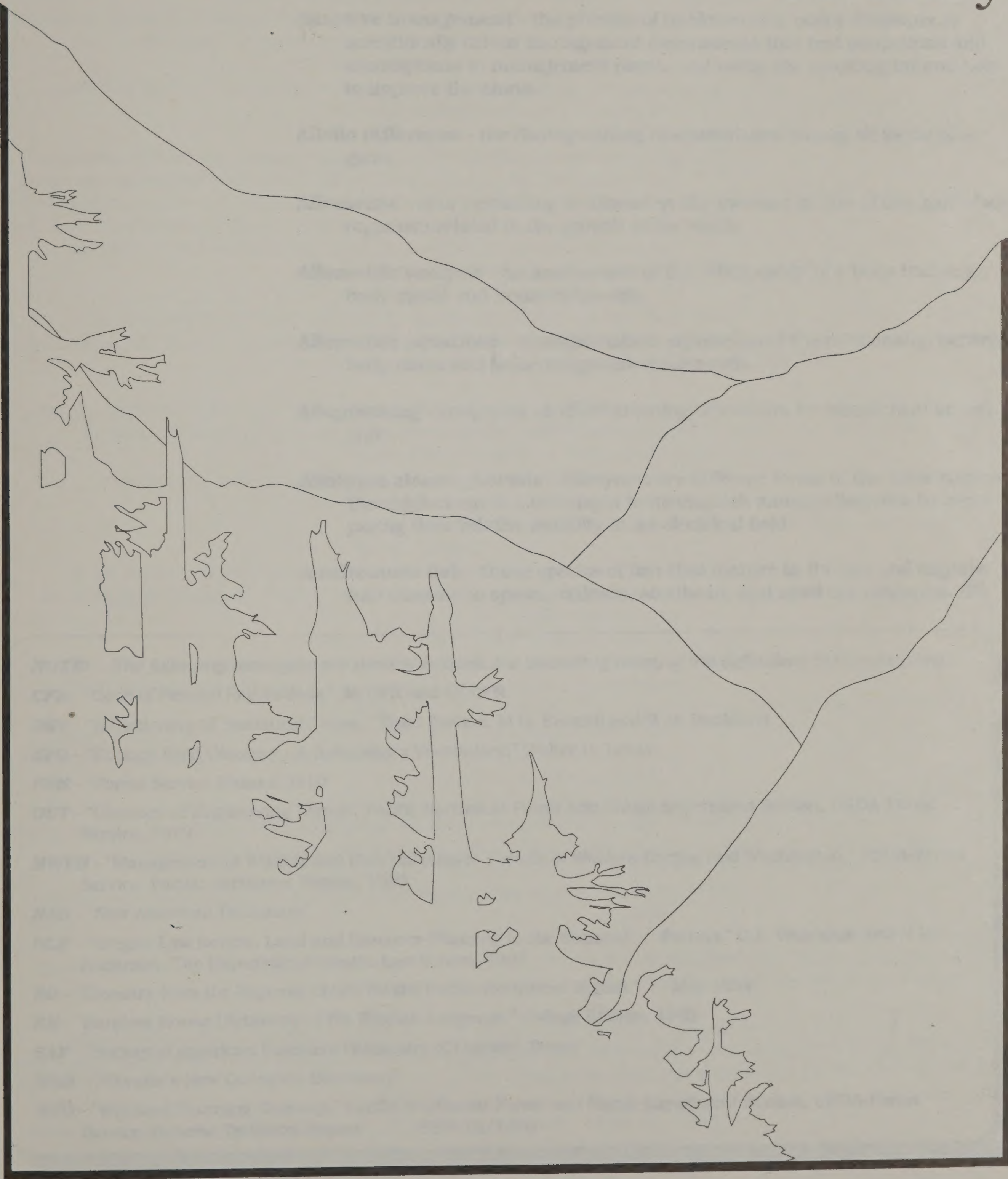
The development of a recovery plan for the northern spotted owl may be the most important effort of its kind since the passage of the Act. The potential implications for the survival of the owl, with respect to other economic, social and environmental values, are significant. The results of your work could well have major effects on land management at both the Federal and non-Federal levels, and also help to set a precedent for future recovery teams working on plans for other listed species. Accordingly, your development of the recovery plan for the northern spotted owl has my highest expectations as well as my full encouragement and support.

Please keep me fully informed as milestones in the preparation of the draft recovery plan are accomplished.

cc: Members of the Northern Spotted Owl Recovery Team

Appendix L

Glossary



50-11-40 rule - a guideline developed to provide habitat conditions adequate for movement of juvenile and adult owls across the landscape. It requires that 50 percent of the forest within a quarter-township be maintained with an average tree dbh of at least 11 inches and 40 percent canopy closure.

Activity center - an area of concentrated activity of either a pair of spotted owls or a territorial single owl.

Adaptive management - the process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans.

Allelic difference - the distinguishing characteristics among all forms of a gene.

Allometric - of or pertaining to allometry: the increase in size of one part of an organism related to the growth of the whole.

Allometric analysis - an assessment of the relationship of a body trait (e.g., body mass) and home range size.

Allometric equations - a mathematical expression of the relationship between body mass and home range size among owls.

Allopreening - reciprocal or ritual cleaning of feathers by members of an owl pair.

Allozyme electrophoresis - Allozymes are different forms of the same enzyme. Electrophoresis is a technique to distinguish among allozymes by comparing their relative mobility in an electrical field.

Anadromous fish - those species of fish that mature in the sea and migrate into streams to spawn. Salmon, steelhead, and shad are examples. *RG*

NOTE: *The following acronyms are used to indicate the sources of many of the definitions in this glossary.*

CFR - "Code of Federal Regulations," 36 CFR and 40 CFR

DST - "A Dictionary of Statistical Terms," Third Edition, M.G. Kendall and W.R. Buckland

EFG - "Ecology Field Glossary - A Naturalist's Vocabulary," Walter H. Lewis

FSM - "Forest Service Manual 2410"

GET - "Glossary of Engineering Terms", Pacific Northwest Forest and Range Experiment Station, USDA-Forest Service, 1979

MWFH - "Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington," USDA-Forest Service, Pacific Northwest Region, 1985

NAD - "New American Dictionary"

OLR - "Oregon Law Review, Land and Resource Planning in the National Forests," C.F. Wilkinson and H.M. Anderson, The University of Oregon Law School, 1985

RG - "Glossary from the Regional Guide for the Pacific Northwest Region," May 1984

RH - "Random House Dictionary of the English Language," College Edition, 1969

SAF - "Society of American Foresters Dictionary of Forestry Terms"

WEB - "Webster's New Collegiate Dictionary"

WPG - "Wildland Planning Glossary," Pacific Southwest Forest and Range Experiment Station, USDA-Forest Service, General Technical Report PSW 13/1976

Aspect - the direction a slope faces with respect to the cardinal compass points. *GET*

Autocorrelation - a measure of the similarity of consecutive numbers in a temporal, or other one-dimensional, series of observations.

Basal area - the area of the cross-section of a tree stem near its base, generally at breast height and including bark. *SAF*

Biological diversity - the variety of life and its processes, including complexity of species, communities, gene pools, and ecological functions.

Biological growth potential - the average net growth attainable in a fully stocked natural forest stand. *RG*

Biological unit management - Forest Service usage. Any unit for management of a particular species or any unit of intensive or special management. The term includes any big-game management unit as recognized by a cooperating state, even though it may not be strictly a herd unit. In the case of fisheries management, the term may include a drainage system. *WPG*

Biomass - the total quantity (at any given time) of living organisms of one or more species per unit of space (species biomass), or of all the species in a biotic community (community biomass). *RG*

Birth-pulse population - a population assumed to produce all of its offspring at an identical, and instantaneous, point during the annual cycle.

BLM - Bureau of Land Management, U.S. Department of the Interior.

Blowdown - trees felled by high winds.

Board foot - lumber or timber measurement term. The amount of wood contained in an unfinished board 1 inch thick, 12 inches long, and 12 inches wide. *WPG*

Breast height - a standard height from average ground level for recording diameter, girth, or basal area, generally 4.5 feet (1.37 meters). *GET*

Broadcast burn - allowing a prescribed fire to burn over a designated area within well-defined boundaries for reduction of fuel hazard or as a silvicultural treatment, or both. *RG*

Brooms (as in mistletoe) - a cluster of branches, radiating from a single point, that results from damage in a tree from agents such as mistletoe.

BT - *Bacillus Thuringiensis*, a bacterium used for biological control of spruce budworm.

Cambium - the layer of tissue between the bark and wood in a tree or shrub. New bark and wood originate from this layer.

Canopy - a layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand.

Canopy closure - the degree to which the crowns of trees are nearing general contact with one another. Generally measured as the percent of the

ground surface that would be covered by a vertical projection of foliage in the crowns of trees.

Capability - the potential of an area of land to produce resources, supply goods and services, and allow resource uses. Capability depends upon current vegetation conditions and site conditions such as climate, slope, landform, soils, and geology. *RG*

Center of activity - the nest site of a breeding pair of owls or primary roost area of a territorial individual owl.

CFR - Code of Federal Regulation.

Checkerboard ownership - a land ownership pattern in which every other section (square mile) is in federal ownership as a result of federal land grants to early western railroad companies.

Class E (fire) - a fire that extends over an area ranging from 300 to 1,000 acres.

Clear-cut - an area where the entire stand of trees has been removed in one cutting. *SAF*

Climax - the culminating stage in plant succession for a given site where the vegetation has reached a highly stable condition. *RG*

Closed sapling pole - sapling and pole stands which are characterized by a closed tree canopy and very little ground cover. Tree crown closure will exceed 60 percent and often reaches 100 percent.

Cluster - an area that contains habitat capable of supporting three or more breeding pairs of spotted owls with overlapping or nearly overlapping home ranges.

Clutch - the number of eggs laid by a female bird at one time. *EFG*

Cohort - individuals all resulting from the same birth-pulse, and thus all of the same age.

Colonization - the establishment of a species in an area not currently occupied by that species. Colonization often involves dispersal across an area of unsuitable habitat.

Conferencing - informal consultation that takes place between the U.S. Fish and Wildlife Service and another federal agency when it is determined that a proposed federal action may jeopardize the continued existence of a species proposed as threatened or endangered or result in adverse modification of proposed critical habitat.

Confidence interval - an interval that is calculated from a series of samples intended to estimate the value of a parameter. The confidence level is the probability that the true value of the parameter falls within the confidence interval.

Confidence level - the probability that the true value for a parameter is included within the confidence interval calculated for a sample of that parameter.

Congressionally classified and designated areas - areas that require congressional enactment for their establishment, such as national wilderness areas, national wild and scenic rivers, and national recreation areas. *RG*

Conifer - a tree belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones (hence coniferous) and needle-shaped or scale-like leaves. *SAF*

Connectivity - a measure of the extent to which intervening habitat truly connects DCAs for juvenile spotted owls dispersing among them.

Conservation - the process or means of achieving recovery.

Conspecifics - belonging to or pertaining to the same species.

Consultation - a formal interaction between the U.S. Fish and Wildlife Service and another federal agency when it is determined that the agency's action may affect a species that has been listed as threatened or endangered or its critical habitat.

Contiguous habitat - habitat suitable to support the life needs of owls that is distributed continuously or nearly continuously across the landscape.

Corridor - a defined tract of land, usually linear, through which a species must travel to reach habitat suitable for reproduction and other life-sustaining needs.

Cost efficiency - the usefulness of specified inputs (costs) to produce specified outputs (benefits). In measuring cost efficiency, some outputs, including environmental, economic, or social impacts, are not assigned monetary values, but are achieved at specified levels in the least costly manner. Cost efficiency usually is measured using present net value, although use of benefit-cost ratios and rates-of-return may be appropriate. *RG*

Critical habitat - specific areas within the geographical area occupied by a species on which are found those physical or biological features essential to conservation of the species.

Crown - the upper part of a tree or other woody plant which carries the main system of branches and the foliage. *SAF*

Crown closure - see canopy closure.

CWD (coarse woody debris) - portion of a tree that has fallen or been cut and left in the woods. Usually refers to pieces at least 20 inches in diameter.

DBH - diameter at breast height. The diameter of a tree measured 4 feet 6 inches from the ground. *RG*

DCA - designated conservation area.

Defoliators - insects that feed on foliage and thus act to remove some or all of the foliage from a tree, shrub, or herb.

Demographic model - a model that predicts the future state of an animal population based on its birth and death rates.

Demography - the quantitative analysis of population structure and trends; population dynamics. *EFG*

Density, biological population - the number or size of a population in relation to some unit of space. It is usually expressed as the number of individuals or the population biomass per unit area or volume. *RG*

Depauperate - poorly developed. In biology, it usually refers to an area that has relatively few plant and animal species.

Designated conservation area (DCA) - a contiguous area of habitat to be managed and conserved for spotted owls. This general description can be applied to two categories:

DCA 1 - category of DCA intended to support at least 20 pairs of spotted owls.

DCA 2 -category of DCA intended to support one to 19 pairs of spotted owls.

Dispersal - the movement, usually one way and on any time scale, of plants or animals from their point of origin to another location where they subsequently produce offspring.

Dispersal capability - ability of members of a species to move from their area of birth to another suitable location and subsequently breed.

Dispersal habitat - habitat that supports the life needs of an individual animal during dispersal. Generally satisfies needs for foraging, roosting, and protection from predators.

Distribution (of a species) - the spatial arrangement of a species within its range.

Disturbance - a significant change in structure and/or composition caused by natural events such as fire and wind or human-caused events such as cutting.

Diversity - see biological diversity.

Down log - portion of a tree that has fallen or been cut and left in the woods.

Early seral stage forests - Stage in forest development that includes seedling, sapling, and pole-sized trees.

East side forests - the 12 national forests in Washington, Oregon, and California that lie partly or wholly east of the Cascade Mountain Range crest: Colville, Deschutes, Fremont, Klamath, Malheur, Ochoco, Okanogan, Shasta-Trinity, Umatilla, Wallowa-Whitman, Wenatchee, and Winema National Forests. *RG*

Ecosystem - an interacting system of organisms considered together with their environment; for example, marsh, watershed, and lake ecosystems. *RG*

Edge - where plant communities meet or where successional stages or vegetative conditions within plant communities come together. *RG* See also edge contrast and horizontal diversity.

Edge contrast - a qualitative measure of the difference in structure of two adjacent vegetated areas; for example, "low," "medium," or "high" edge contrast. *RG*

Electrophoresis - a technique used to distinguish among allozymes by comparing their relative mobility in an electrical field.

Empirical - derived from direct observation or experimentation.

Endangered species - any species of animal or plant that is in danger of extinction throughout all or a significant portion of its range; plant or animal species identified by the Secretary of the Interior as endangered in accordance with the 1973 Endangered Species Act. *RG*

Endemic - a species that is unique to a specific locality.

Environmental analysis - an analysis of alternative actions and their predictable short- and long-term environmental effects, incorporating physical, biological, economic, and social considerations. *RG*

Environmental assessment - a concise public document required by the regulations implementing the National Environmental Policy Act. *RG*

Environmental stochasticity - random variation in environmental attributes such as temperature, precipitation, and fire frequency.

Epiphyte - a plant that grows upon another plant and that is nonparasitic. Most of the plant's necessary moisture and nutrients are derived from the atmosphere. *RG*

Even-aged forest - a forest stand composed of trees with less than a 20-year difference in age.

Even-aged management - the application of a combination of actions that result in the creation of stands in which trees of essentially the same age grow together. Managed even-aged forests are characterized by a distribution of stands of varying ages (and, therefore, tree sizes) throughout the forest area. The difference in age among trees forming the main canopy level of a stand usually does not exceed 20 percent of the age of the stand at harvest rotation age. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for harvesting. Clear-cut, shelterwood, or seed tree cutting methods produce even-aged stands. *RG*

Extended rotation - a period of years that is longer than the time necessary to grow timber crops to a specified condition of maturity. *SAF* See rotation.

Extended rotation age - a point in time when trees are harvested or planned to be harvested that is beyond the age when harvest ordinarily would occur. *SAF* See rotation age.

Extinct - A species is extinct when it no longer exists. *EFG*

Extirpation - the elimination of a species from a particular area.

Fecundity - number of female young produced per adult female.

Fire regime - the characteristic frequency, extent, intensity, severity, and seasonality of fires in an ecosystem.

Fire severity - the degree to which a site has been altered or disrupted by fire. Severity reflects fire intensity and residence time.

Fledge - to rear until ready for flight or independent activity. *WEB*

Floaters - nonbreeding adults and subadults that move and live within a breeding population, often replacing breeding adults that die; nonterritorial individuals.

Food chain - organisms that are interrelated in their feeding habits, each feeding upon organisms that are lower in the chain and in turn being fed on by organisms higher in the chain.

Forest fragmentation - the change in the forest landscape, from extensive and continuous forests of old-growth to a mosaic of younger stand conditions.

Fragmentation - see forest fragmentation.

Fuel loading - the amount of combustible material present per unit of area, usually expressed in tons per acre.

FWS - Fish and Wildlife Service, U.S. Department of the Interior.

GIS - geographical information system. This is a computer system capable of storing and manipulating spatial (i.e., mapped) data.

Group selection cutting - removal of groups of trees ranging in size from a fraction of an acre up to about 2 acres. Area cut is smaller than the minimum feasible under even-aged management for a single stand. *RG*

Guideline - a policy statement that is not a mandatory requirement (as opposed to a standard, which is mandatory). *RG*

HA (hectare) - a measure of area in the metric system equal to approximately 2.5 acres.

Habitat - the place where a plant or animal naturally or normally lives and grows. *RG*

Habitat capability - the estimated number of pairs of spotted owls that can be supported by the kind, amount, and distribution of suitable habitat in the area. As used in the recovery plan, this means the same as capability to support spotted owl pairs.

Harvest cutting method - methods used to harvest trees. Harvest cutting methods are classified as even-aged and uneven-aged. *RG*

HCA (habitat conservation area) - as proposed by the Interagency Scientific Committee, a contiguous block of habitat to be managed and conserved for breeding pairs, connectivity, and distribution of owls; application may vary throughout the range according to local conditions.

HCP (habitat conservation plan) - an agreement between the Secretary of the Interior and either a private entity or a state that specifies conservation measures that will be implemented in exchange for a permit that would allow taking of a threatened or endangered species.

Home range - the area within which an animal conducts its activities during a defined period of time.

Home range of a pair - the sum of the home ranges of each member of a pair minus the area of home range overlap.

Horizontal diversity - the distribution and abundance of plant and animal communities and successional stages across an area of land; the greater the number of communities, the higher the degree of horizontal diversity. *RG*

Hummocky - a landscape characterized by small, well-drained areas rising above the general level of poorly-drained land.

Hybrid - an offspring that results from the mating of individuals of different races or species.

Hybridization - the crossing or mating of two different varieties of plants or animals.

Incidental take - "take" of a threatened or endangered species that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity.

Inholding - land belonging to one landowner that occurs within a block of land belonging to another. For example, small parcels of private land that occur inside national forests.

Integrated pest management - a process for selecting strategies to regulate forest pests in which all aspects of a pest-host system are studied and weighed. Regulatory strategies are based on sound silvicultural practices and ecology of the pest-host system and consist of a combination of tactics such as timber stand improvement plus selective use of pesticides. *RG*

Interagency Spotted Owl Subcommittee - a subcommittee of the Oregon-Washington Interagency Wildlife Committee that was formed to recommend guidelines to federal land management agencies for the protection of the northern spotted owl.

Interspecific - occuring among members of different species.

Interspecific competition - the condition of rivalry that exists when a number of organisms of different species use common resources that are in short supply; or, if the resources are not in short supply, the condition that occurs when the organisms seeking that resource nevertheless harm one or another in the process. Competition usually is confined to closely related species that eat the same sort of food or live in the same sort of place. Competition typically results in ultimate elimination of the less effective organism from that ecological niche. *WPG*

Intraspecific - occuring among members of single species.

ISC (Interagency Scientific Committee) - a committee of scientists that was established by the U.S. Forest Service, U.S. Bureau of Land Management, U./S. Fish and Wildlife Service, and National Park Service, to develop a conservation strategy for northern spotted owls.

Isolate - a population that is isolated. See isolation.

Isolation - absence of genetic crossing among populations because of distance or geographic barriers. *SAF*

Jamison strategy - a spotted owl conservation strategy adopted by the U.S. Bureau of Land Management that included some but not all of the major provisions of the ISC strategy.

Jeopardy - a finding made through consultation under the Endangered Species Act that the action of a federal agency is likely to jeopardize the continued existence of a threatened or endangered species.

Kuchler vegetative types - potential natural vegetation of the coterminous United States, classified by Kuchler. *RG*

Lambda - the rate of population change (population size in year 2 divided by the population size in year 1).

Landsat - a satellite that produces imagery used in remote sensing of forests. Analysis of this imagery produces maps of vegetation condition.

Late seral stage forest - stage in forest development that includes mature and old-growth forest.

M - thousand. *RG*

Managed forest - refers to any forestland, including owl habitat, that is treated with silivicultural practices and/or harvested. Generally applied to land that is harvested on a scheduled basis and contributes to an allowable sale quantity.

Managed pair areas - In some portions of the range it is necessary to provide additional protection for matrix pairs and territorial singles. This consists of delineating a core habitat area, plus additional acreage of suitable habitat around the core. The acreage to be delineated around the core varies throughout the range, based on data for pairs in that area. The suitable acreage must be delineated within an area equal to the mean home range for that province. Appropriate silvicultural treatment is encouraged in suitable and unsuitable habitat in the acreage around the core.

Management prescription - the management practices and intensity selected and scheduled for application on a specific area to attain multiple-use and other goals and objectives. *RG*

Matrix - land within the range of the northern spotted owl that lies outside of category 1 and 2 designated conservation areas.

Mature stand - A mappable stand of trees for which the annual net rate of growth has culminated. Stand age, diameter of dominant trees, and stand structure at maturity vary by forest cover types and local site conditions. Mature stands generally contain trees with a smaller average diameter, less age class variation, and less structural complexity than old-growth stands of the same forest type. Mature stages of some forest types are suitable habitat for spotted owls; however, mature forests are not always spotted owl habitat, and spotted owl habitat is not always mature forest.

MBF - thousand board feet. Lumber or timber measurement term. *RG*

Mean - a central value of a series or set of observations obtained by dividing the sum of all observations by the number of observations. *SAF*

Mesic - pertaining to or adapted to an area that has a balanced supply of water. Neither wet nor dry.

Metapopulation - a population comprised of a set of local populations that are linked by migrants, allowing for recolonization of unoccupied habitat patches after local extinction events.

Minimum viable population - the low end of the viable population range. *RG*

Mixed conifer - as used in this document, the term "mixed conifer" refers to stands of trees, made up of pine, Douglas-fir, and true firs, that are generally found east of the Cascades.

Mixed-conifer forest - a forest community that is dominated by two or more coniferous species.

Mixed-evergreen forest - a forest community that is dominated by two or more species of broad-leaved hardwoods whose foliage persists for several years: important western species include madrone, tanoak, chinquapin, canyon live oak, and California-laurel.

MM - million. *RG*

MMBF - million board feet. Lumber or timber measurement term.

Modal - of or relating to a statistical mode that is the highest-frequency value for a variable in a data set. *WEB*

Model - an idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it; a mathematical representation of the relationships under study. The term model is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations.

Monitoring - a process of collecting information to evaluate whether objectives of a management plan are being realized.

Multiple use - the management of renewable resources so that they are utilized in the combination that will best meet the needs of people. *RG*

Multistoried - term applied to forest stands that contain trees of various heights and diameter classes and therefore support foliage at various heights in the vertical profile of the stand.

Multivariate analysis - a field of statistics in which multiple variables are used to compare sample groups. Multivariate analysis contrasts with univariate analysis, in which single variables are used to compare sample groups.

NAAQS - National Ambient Air Quality Standards. *RG*

Natal area - the location where an animal was born.

NEPA - National Environmental Policy Act of 1969. *RG*

Nesting, roosting, and foraging (NRF) habitat - forest vegetation with appropriate structure and composition to meet some or all of the life needs of northern spotted owls.

Nexus - a means of connection. Often used in a legal context to refer to the legal connection between one action and another.

NF - National forest. *RG*

NFMA - National Forest Management Act of 1976. *RG*

Nocturnal - referring to organisms that are active or functional at night. *EFG*

Nonmarket - products derived from resources that do not have a well-established market value; for example, recreation, wilderness, wildlife. *RG*

Occupancy rate - in reference to spotted owls, the percent of inventoried spotted owl habitat that is estimated to be occupied by breeding pairs of spotted owls.

Off-road vehicles (ORVs) - vehicles such as motorcycles, all-terrain vehicles, four-wheel drive vehicles, and snowmobiles. *RG*

Old-growth - a forest stand with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; a high incidence of large trees with large, broken tops, and other indications of decadence; numerous large snags; and heavy accumulations of logs and other woody debris on the ground.

Old-growth species - plant and animal species that exhibit a strong association with old-growth forests.

Old-growth stand - a mappable area of old-growth forest.

Oregon-Washington Interagency Wildlife Committee - a committee composed of administrators from federal and state agencies; including the U.S. Forest Service, the U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, the Oregon Department of Fish and Wildlife, and the Washington Department of Game.

Overstory - trees that provide the uppermost layer of foliage in a forest with more than one roughly horizontal layer of foliage.

Owl site - any site where there has been a recent or historic observation of a single spotted owl or a pair of owls.

Pair site - an amount of habitat that is considered capable of supporting one pair of spotted owls.

Phenology - the annual recurrence of plant and animal phenomena that is influenced by seasonal and other environmental changes, e.g., flowering of plants, ripening of fruit.

Physiographic province - a geographic region in which climate and geology have given rise to a distinct array of landforms. Biology and habitat relationships of spotted owls vary by physiographic province due to differences in climate, vegetation, and productivity of habitats.

Platform nest - a relatively flat nest constructed on a supporting structure such as a broad branch.

Population density - number of individuals of a species per unit area.

Population dynamics - the aggregate of changes that occur during the life of a population. Included are all phases of recruitment and growth, senility, mortality, seasonal fluctuation in biomass, and persistence of each year class and its relative dominance, as well as the effects that any or all of these factors exert on the population. *SAF*

Population viability - probability that a population will persist for a specified period of time across its range despite normal fluctuations in population and environmental conditions.

Potential habitat - a stand of trees of a vegetation type used by spotted owls that is not currently suitable, but is capable of growing or developing into suitable habitat in the future. In general, potential habitats are stands in the earlier successional stages of forest types used by spotted owls.

Power - the probability of rejecting the null hypotheses in a statistical test.

Precommercial thinning - the practice of removing some of the trees less than merchantable size from a stand so that remaining trees will grow faster. *RG*

Predator - any animal that preys externally on others, i.e., that hunts, kills, and generally feeds on a succession of hosts, i.e., the prey. *SAF*

Prescribed fire - a fire burning under specified conditions that will accomplish certain planned objectives. The fire may result from planned or unplanned ignitions. *RG*

Presuppression - activities organized in advance of fire occurence to ensure effective suppression action. *RG*

Protective management - measures taken by nonfederal entities to conserve spotted owls and/or their habitat; measures may include participation in conservation planning (as defined in Endangered Species Act section 10) or other actions that benefit owls; entities may be states, private landowners, Indian tribes, or others.

Province - see physiographic province.

Quarter-township - an area approximately 3 miles square containing nine sections of land.

Radio-telemetry - automatic measurement and transmission of data from remote sources via radio to a receiving station for recording and analysis. In this recovery plan, it refers to the tracking of spotted owls by means of small radio transmitters attached to them. *NAD*

Random - being or relating to a set or to an element of a set each of whose elements has equal probability of occurrence; also characterized by procedures to obtain such sets or elements. *WEB*

Range (of a species) - the area or region over which an organism occurs. *EFG*

Recovery - action that is necessary to reduce or resolve the threats that caused a species to be listed as threatened or endangered.

Recruitment - the addition to a population from all causes, i.e., reproduction, immigration, and stocking. Recruitment may refer literally to numbers born or hatched or to numbers at a specified stage of life such as breeding age or weaning age. *SAF*

Reforestation - the natural or artificial restocking of an area with forest trees; most commonly used in reference to artificial restocking. *RG*

Refugia - havens of safety where populations have high probability of surviving periods of adversity.

Regeneration - the actual seedlings and saplings existing in a stand; or the act of establishing young trees naturally or artificially. *RG*

Regulated forest - a theoretical managed forest from which the same acreage of stands can be harvested annually in perpetuity.

Regulations - generally refers to the Code of Federal Regulations.

Rescue effect - immigration of new individuals sufficient to maintain a population that might otherwise decline toward extinction.

Reserved land - lands that have been removed from the acreage base used to calculate timber yields. These lands often have a preservation or protection status. Wildernesses, research natural areas, and national recreation areas are examples of reserved lands.

Reserved pair areas - In those portions of the species' range where habitat and owl populations were inadequate to apply the criteria creating DCAs 1 and 2, individual pair areas were also reserved. These are areas of suitable habitat identified for pairs and territorial single owls. The acreage of these areas varies throughout the range, based on data for pairs in each province. All suitable habitat is reserved within an area equal to the mean home range for that province.

Residual habitat area - a 100-acre area of nesting, roosting, and foraging habitat encompassing the activity center for a pair of owls or a territorial single owl in the matrix.

Residual stand - the trees that remain standing after some event such as selection cutting. *RG*

Riparian area - a geographically delineated area with distinctive resource values and characteristics that comprises aquatic and riparian ecosystems. This includes floodplains, wetlands, and all areas within a horizontal distance of approximately 100 feet from the normal line of high water of a stream channel or from the shoreline of a standing body of water. *RG*

Roost - the resting behavior of an animal.

Roost sites - a site where an animal roosts. Can refer to daytime and nighttime roosting. Sites often provide protection from environmental conditions and from predators.

Rotation - the planned number of years between the regeneration of an even-aged stand and its final cutting at a specified stage.

Rotation age - the age of a stand when harvested at the end of a rotation. *RG*

Sanitation salvage - removal of dead, damaged, or susceptible trees primarily to prevent the spread of pests or pathogens and to promote forest hygiene. *RG*

Sapling - a loose term for a young tree no longer a seedling but not yet a pole. It is generally a few feet high and 2 to 4 inches dbh, typically growing vigorously and without dead bark or more than an occasional dead branch. *SAF*

Second-growth - relatively young forests that have developed following a disturbance (for example, wholesale cutting, serious fire, or insect attack) of the previous old-growth forest.

Section 7 - the section of the Endangered Species Act that specifies the roles of interagency coordination in accomplishing the objective of species recovery.

Sensitive species - those species that 1) have appeared in the Federal Register as proposed for classification and are under consideration for official listing as endangered or threatened species; or 2) are on an official state list; or 3) are recognized by the U.S. Forest Service or other management agency as needing special management to prevent their being placed on federal or state lists. *RG*

Seral - a biotic community that is a developmental, transitory stage in an ecological succession. *RG*

Seral species - species associated with an early stage in the development of a biotic community.

Sexual dimorphism - the differences in size, weight, color, or other morphological characteristics that are related to the sex of the animal.

Shelterwood - an even-aged silvicultural system in which the old forest is removed in two or more successive cuttings. *SAF*

Silviculture - the science and practice of controlling the establishment, composition, and growth of forests. *RG*

Sink - population whose average reproductive rate is less than its average rate of mortality: such areas attract immigrants not expected to contribute significantly to future populations. See source.

Slash - the residue left on the ground after timber cutting. It includes unused logs, uprooted stumps, broken or uprooted stems, branches, twigs, leaves, bark, and chips. *RG*

Snag - a standing dead tree. *GET*

Socioeconomic - pertaining to, or signifying the combination or interaction of, social and economic factors. *RG*

SOHA (spotted owl habitat area) - a habitat area designated to support one pair of owls. Such areas were prescribed in some previous plans for northern spotted owl conservation.

SOMA (spotted owl management area) - an area designated to support three pairs of owls with home ranges separated by no more than 1.5 miles. Such areas were prescribed in some previous plans for northern spotted owl conservation.

Source - an actively breeding population that has an average birth rate that exceeds its average death rate; produces an excess number of juveniles that may disperse to other areas.

Species - 1) a group of individuals that have their major characteristics in common and are potentially interfertile. *EFG* 2) the Endangered Species Act defines species as including any species or subspecies of plant or animal. Distinct populations of vertebrates also are considered to be species under the act.

Stand (tree stand) - an aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement, and condition as to be distinguishable from the forest in adjoining areas. *RG*

Stand condition - a description of the physical properties of a stand such as crown closure or diameters. *SAF*

Stand-replacing event - a disturbance that is severe enough over a large enough area (for example, 10 acres) to virtually eliminate an existing stand of trees and initiate a new stand.

Standards and guidelines - standards and guidelines are the primary statement of direction for land managers. In the recovery plan, standards and guidelines are recommended as actions necessary to accomplish recovery.

Stochastic - random, uncertain; involving a random variable.

Stochastic model - a model that includes representation of random events.

Stocking - the degree of occupancy of an area of land by trees as measured by basal area or number of trees and as compared to a stocking standard; that is, the basal area or number of trees required to fully use the growth potential of the land. *RG*

Stumpage - the value of standing timber.

Subadult - a young spotted owl that has dispersed but has not yet reached breeding age. Subadults are in their second, or in some cases, third year of life.

Subpopulation - a well-defined set of interacting individuals that comprise a proportion of a larger, interbreeding population.

Subspecies - a population of a species occupying a particular geographic area, or less commonly, a distinct habitat, capable of interbreeding with other populations of the same species. *EFG*

Successional stage - a stage or recognizable condition of a plant community that occurs during its development from bare ground to climax; for example, coniferous forests in the Blue Mountains progress through six recognized stages: grass-forb; shrub-seedling; pole-sapling; young; mature; old-growth. *RG* See also Seral.

Suitable habitat - in the recovery plan, an area of forest vegetation with the age-class, species of trees, structure, sufficient area, and adequate food source to meet some or all of the life needs of the northern spotted owl. See also nesting, roosting, and foraging habitat.

Suitable spotted owl habitat - See suitable habitat.

Superior habitat - in the recovery plan, habitat selected in excess of availability by the majority of individual northern spotted owls.

Supplemental pair areas - areas on nonfederal lands where habitat is maintained to support spotted owl pairs or territorial singles.

Suppression - the action of extinguishing or confining a fire. *RG*

Survivorship - the proportion of newborn individuals that are alive at a given age. *EFG*

Sustained yield or production - the amount of timber that a forest can produce continuously from a given intensity of management; implies continuous production; a primary goal is to achieve a balance between incremental growth and cutting.

Take -Uunder the Endangered Species Act, take means to harrass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect an animal, or to attempt to engage in any such conduct.

Taking (section 7) - implementing an action that results in take.

Taxon - a category in a scientific classification system, such as class, family, or phylum.

Territorial single - an unpaired owl that is defending a territory.

Territory - the area that an animal defends, usually during breeding season, against intruders of its own species.

Thermoregulation - the physiological and biological process whereby an animal regulates its body temperature.

Threatened species - those plant or animal species likely to become endangered species throughout all or a significant portion of their range within the foreseeable future. A plant or animal species identified by the Secretary of Interior as threatened, in accordance with the 1973 Endangered Species Act. *RG*

Timber classification - the following are definitions of timber classifications:

1. *Nonforest* - land that has never supported forests and land formerly forested where use for timber production is precluded by development or other uses.
2. *Forest* - land at least 10 percent stocked (based on crown cover) by forest trees of any size, or formerly having had such tree cover and not currently developed for nonforest use.
3. *Suitable* - commercial forestland identified as appropriate for timber production.
4. *Unsuitable* - forestland withdrawn from timber utilization by statue or administrative regulation (for example, wilderness), or locally identified as not appropriate for timber production.

Timber harvest schedule - the quantity of timber planned for sale and harvest, by time period, from the area of land administered by a federal agency. The first period, usually a decade, of the selected harvest schedule provides the allowable sale quantity. *RG*

Timber production - the purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use other than for fuelwood. *RG*

Timber stand - see stand.

Timber stand improvement - measures such as thinning, pruning, release cutting, prescribed fire, girdling, weeding, or poisoning of unwanted trees aimed at improving growing conditons for the remaining trees. *RG*

Trophic level - the level in the food chain at which an organism sustains itself.

Understory - the trees and other woody species growing under a more or less continuous cover of branches and foliage formed collectively by the upper portions of adjacent trees and other woody growth. *WPG*

Uneven-aged management - the application of a combination of actions needed to simultaneously maintain continuous tall forest cover, recurring

regeneration of desirable species, and the orderly growth and development of trees through a range of diameter or age classes. Cutting methods that develop and maintain uneven-aged stands are single-tree selection and group selection. *RG*

Unsuitable habitat - forested lands that currently do not meet the habitat needs of spotted owls for nesting, roosting, or foraging, but are ecologically capable of doing so. This habitat is deficient in tree size, canopy closure, and/or stand decadence. It results from timber harvest or natural disturbance. Also referred to as 'potential habitat.'

USDA - U.S. Department of Agriculture.

USDI - U.S. Department of the Interior.

Verified pair - a pair of spotted owls of specified breeding status identified according to a standard field survey procedure.

Vertical diversity - the diversity in a stand that results from the complexity of the above ground structure of the vegetation; the more tiers of vegetation or the more diverse the species makeup (or both), the higher the degree of vertical diversity. *RG* See also horizontal diversity.

Viability - the ability of a population to maintain sufficient size so that it persists over time in spite of normal fluctuations in numbers; usually expressed as a probability of maintaining a specific population for a specified period.

Viable population - a population that contains an adequate number of individuals appropriately distributed to ensure the long-term existence of the species. *RG*

Vital rates - rates of key demographic functions within a population, such as the birth rate and survival rate.

Vole - any rodent of the genus Microtus and related genera, that resembles rats or mice, but has a relatively short tail. *NAD*

Well distributed - a geographic distribution of habitats that maintains a population throughout a planning area and allows for interaction of individuals through periodic interbreeding and colonization of unoccupied habitats.

West side forests - the 11 national forests within the range of the northern spotted owl in Washington, Oregon, and California that lie west of the Cascade Mountain Range crest. They are the Gifford Pinchot, Mendocino, Mt. Baker-Snoqualmie, Mt. Hood, Olympic, Rogue River, Siskiyou, Siuslaw, Six Rivers, Umpqua, and Willamette National Forests. *RG*

Wetlands - areas that are inundated by surface water or groundwater with a frequency sufficient to support, and under normal circumstances do or would support, a prevalence of vegetative or aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction (Executive Order 11990). *RG*

Wild and scenic rivers - those rivers or sections of rivers designated as such by congressional action under the 1968 Wild and Scenic Rivers Act, as supplemented and amended, or those sections of rivers designated as

wild, scenic, or recreational by an act of the legislature of the state or states through which they flow. Wild and scenic rivers may be classified and administered under one or more of the following categories:

1. *Wild River Areas* - those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America.
2. *Scenic River Areas* - those rivers or sections of rivers that are free of impoundments, with watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads.
3. *Recreational River Areas* - those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past. *RG*

Wilderness - areas designated by congressional action under the 1964 Wilderness Act. Wilderness is defined as undeveloped federal land retaining its primeval character and influence without permanent improvements or human habitation. Wilderness areas are protected and managed to preserve their natural conditions, which generally appear to have been affected primarily by the forces of nature, with the imprint of human activity substantially unnoticeable; have outstanding opportunities for solitude or for a primitive and confined type of recreation; include at least 5,000 acres or are of sufficient size to make practical their preservation, enjoyment, and use in an unimpaired condition; and may contain features of scientific, educational, scenic, or historical value as well as ecologic and geologic interest. *RG*

Wildfire - any wildland fire that is not a prescribed fire. *RG*

Windfall - trees or parts of trees felled by high winds. See also blowdown and windthrow.

Windthrow - a tree or group of trees uprooted by the wind.

Yarding - the moving of logs from the stump to a central concentration area or landing. *RG*

YUM (yarding of unmerchantable material) - moving unmerchantable portions of trees from the stump to a central concentration area.

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and scenic, as determined by an act of Congress or the state or states through which they flow. Wild and scenic rivers may be classified and administered under one or more of the following categories:

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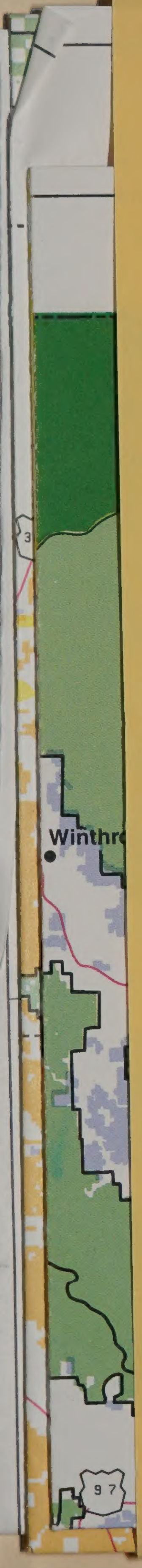
Wildfire - any wildland fire that is not a prescribed fire. BG

Windfall - trees or parts of trees felled by high winds. See also blowdown and windthrow.

Windthrow - a tree or group of trees uprooted by the wind.

Yarding - the movement of logs from the stump to a central concentration area or landing. SO

YUM (yarding of unmerchantable material) - yarding unmerchantable portions of trees from the stump to a central concentration area.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and scenic rivers system by Congress or by designation/nomination by the state or states through which they flow. Wild and scenic rivers may be classified and administered under one or more of the following categories:

1. Wild river areas - Those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America.
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Wildfire - Any wildland fire that is not a prescribed fire. SO

Windfall - Tree or parts of trees felled by high winds. See also blowdown and windthrow.

Windthrow - A tree or group of trees uprooted by the wind.

Yarding - The hauling of logs from the stump to a central concentration area, or landing. SO

YUM (yarding of unmerchantable material) - yarding unmerchantable portions of trees from the stump to a central concentration area.

Designated Conservation Areas (DCAs)

Northern Spotted Owl
DRAFT
Recovery Plan

State of California

Approximate Scale 1:700,000
1992

LEGEND

- National Forest (not reserved)
- Wilderness, National Monument, National Recreation Area
- Bureau of Land Management
- National Park Service
- Other Federal Lands
- State Lands
- Indian Reservations
- State Boundary
- Forest Boundary
- Reserved Lands Boundary
- County Boundary
- Roads

CD-28 Designated Conservation Areas managed for northern spotted owl recovery.

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NOTE
Schematic map; not to scale; intended for display purposes only.

United States Department of the Interior

Map Base: BLM State Map, 1988. State Land Status provided by California Department of Forestry, 1990.

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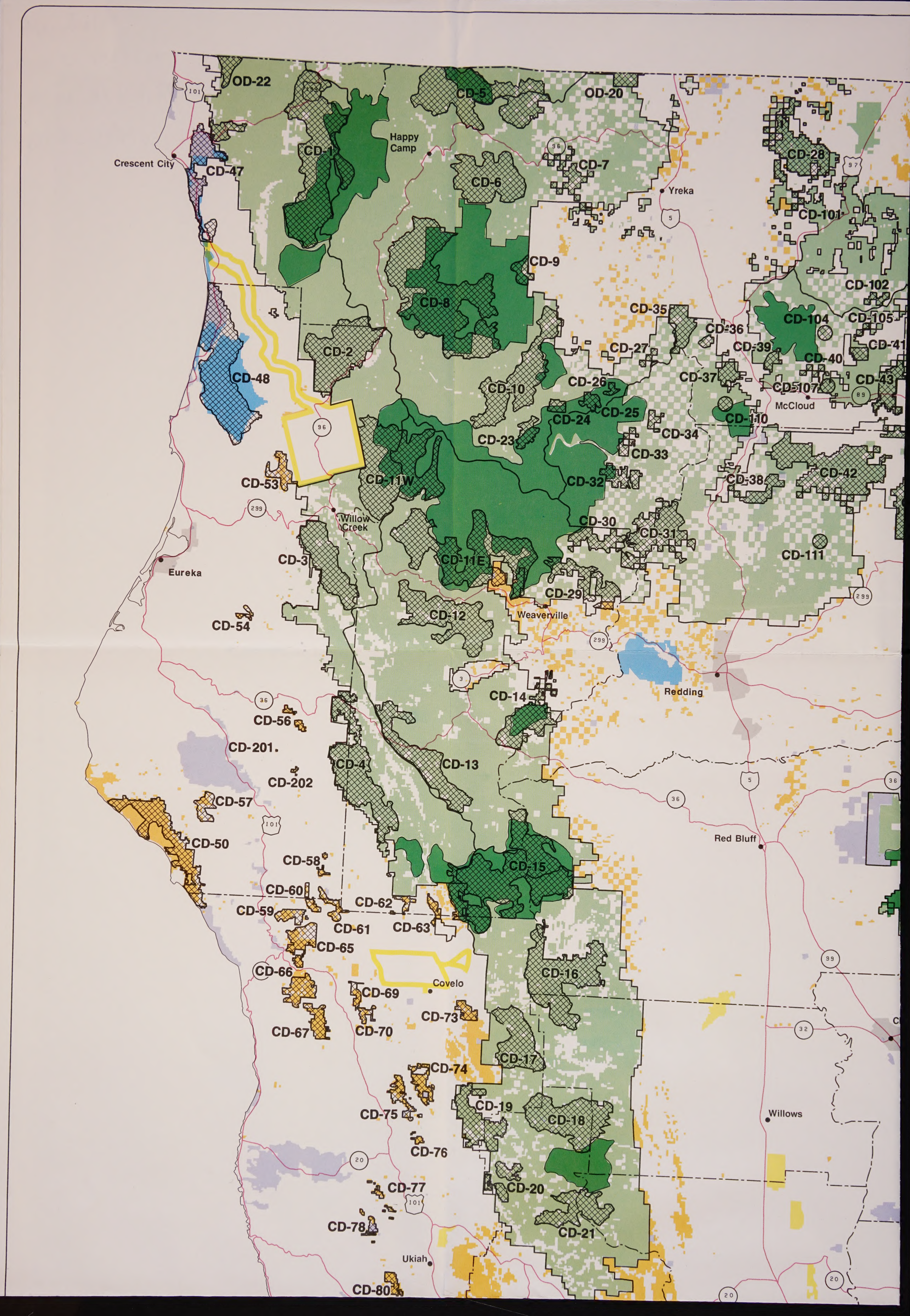

OD-22
OD-20
CD-5
Happy Camp
CD-1
Crescent City
CD-47
CD-7
CD-6
Yreka
CD-28
CD-101
CD-9
CD-102
CD-8
CD-35
CD-104
CD-105
CD-36
CD-39
CD-41
CD-2
CD-27
CD-40
CD-48
CD-26
CD-37
CD-10
CD-107
CD-43
CD-25
McCloud
CD-24
CD-110
CD-23
CD-34
CD-33
CD-42
CD-11W
CD-32
CD-38
CD-53
CD-30
Willow Creek
CD-31
CD-111
CD-3
CD-11E
Eureka
CD-29
CD-12
Weaverville
CD-54
Redding
CD-14
CD-56
CD-201.
CD-13
CD-4
CD-202
CD-57
CD-50
Red Bluff
CD-15
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CD-16
CD-66
Covelo
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CD-70
CD-17
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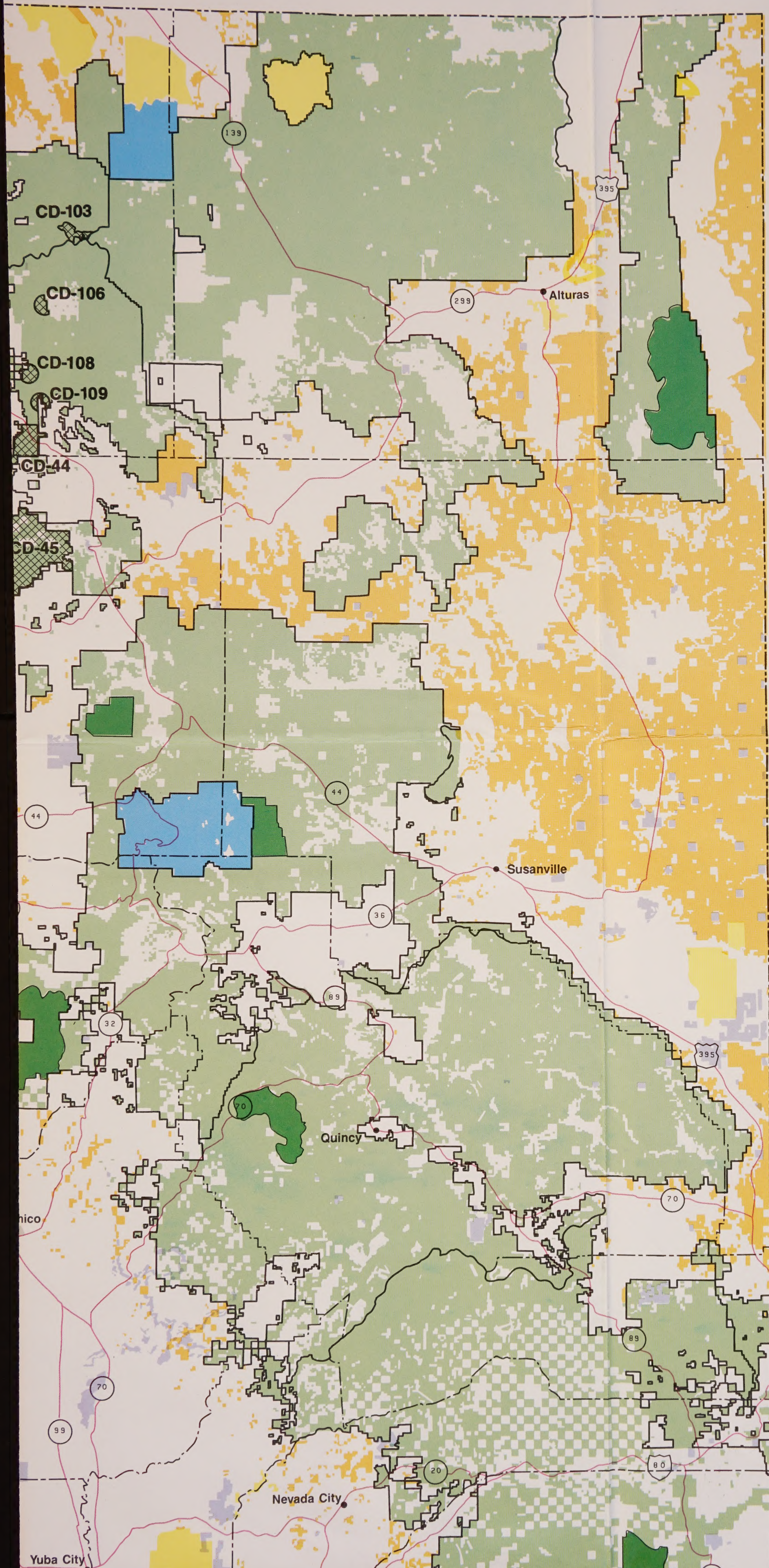
CD-75
CD-18
Willows
CD-76
CD-20
CD-77
CD-21
CD-78
Ukiah
CD-80



Designated Conservation Areas (DCAs)

Northern Spotted Owl *DRAFT* Recovery Plan

State of California

Approximate Scale 1:700,000
1992

LEGEND

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- Bureau of Land Management
- National Park Service
- Other Federal Lands
- State Lands
- Indian Reservations

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- Forest Boundary
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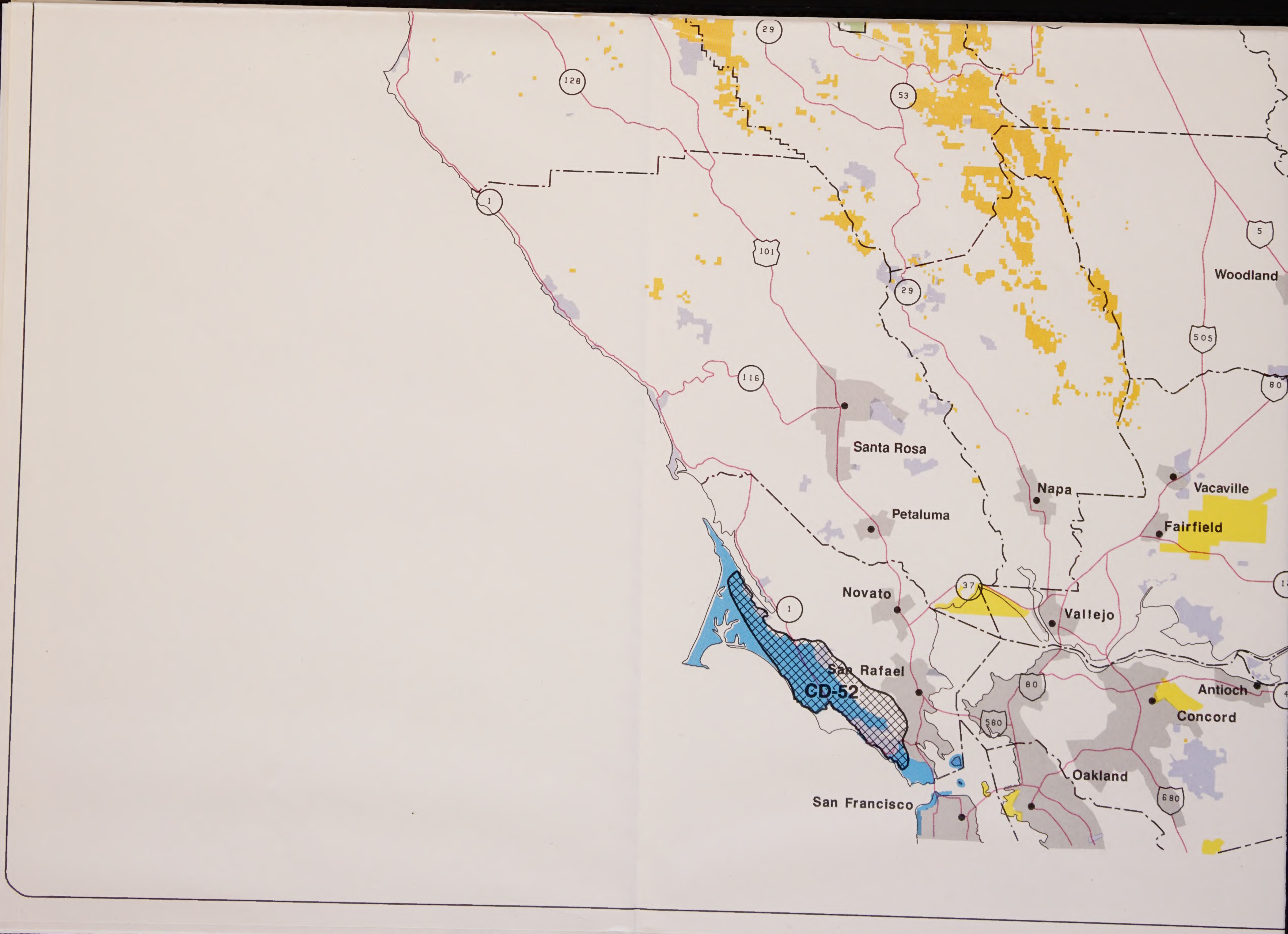
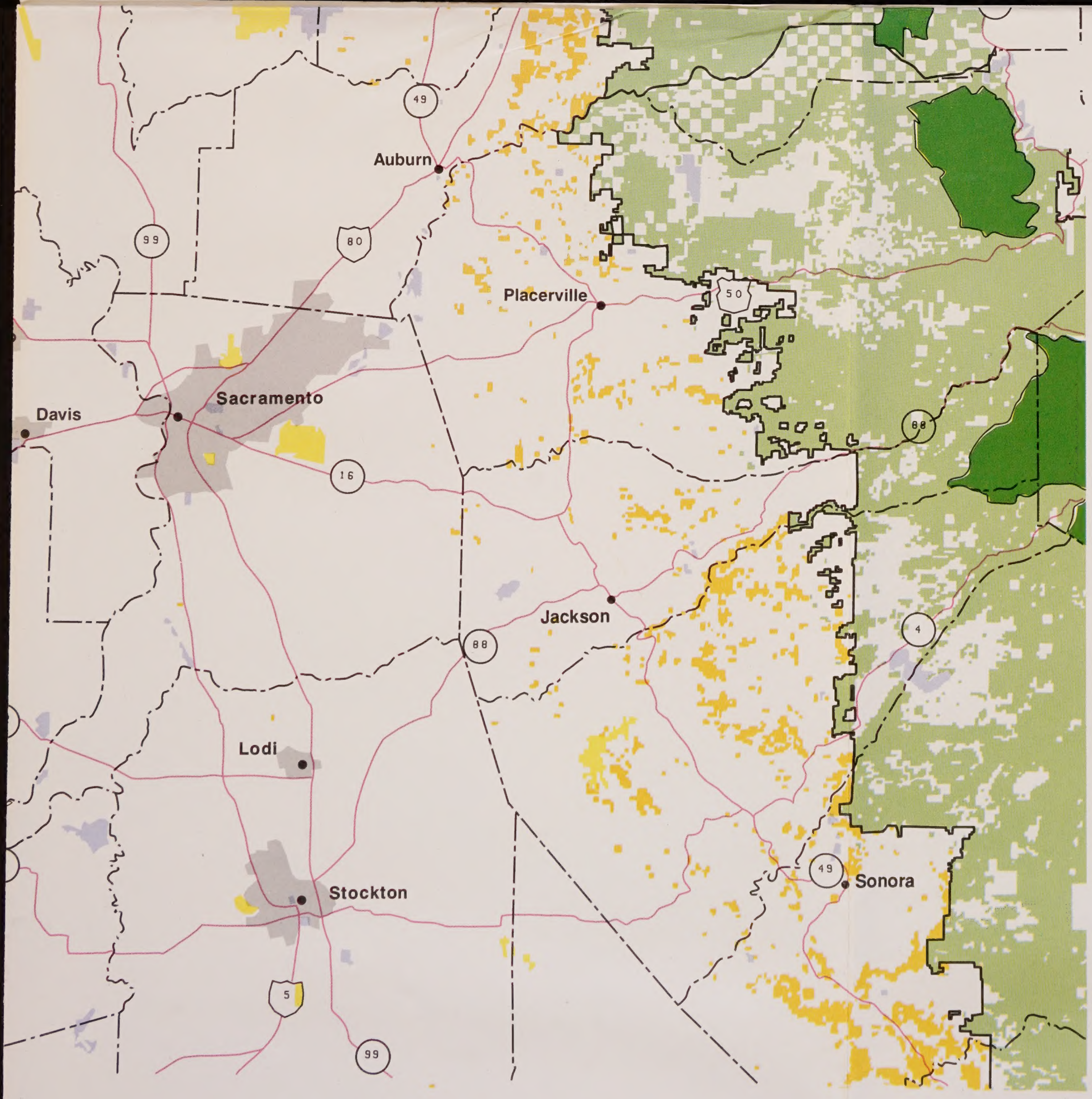


Woodland
Santa Rosa
Napa
Vacaville
Petaluma
Fairfield
Novato
Vallejo
San Rafael
CD-52
Antioch
Concord
Oakland
San Francisco



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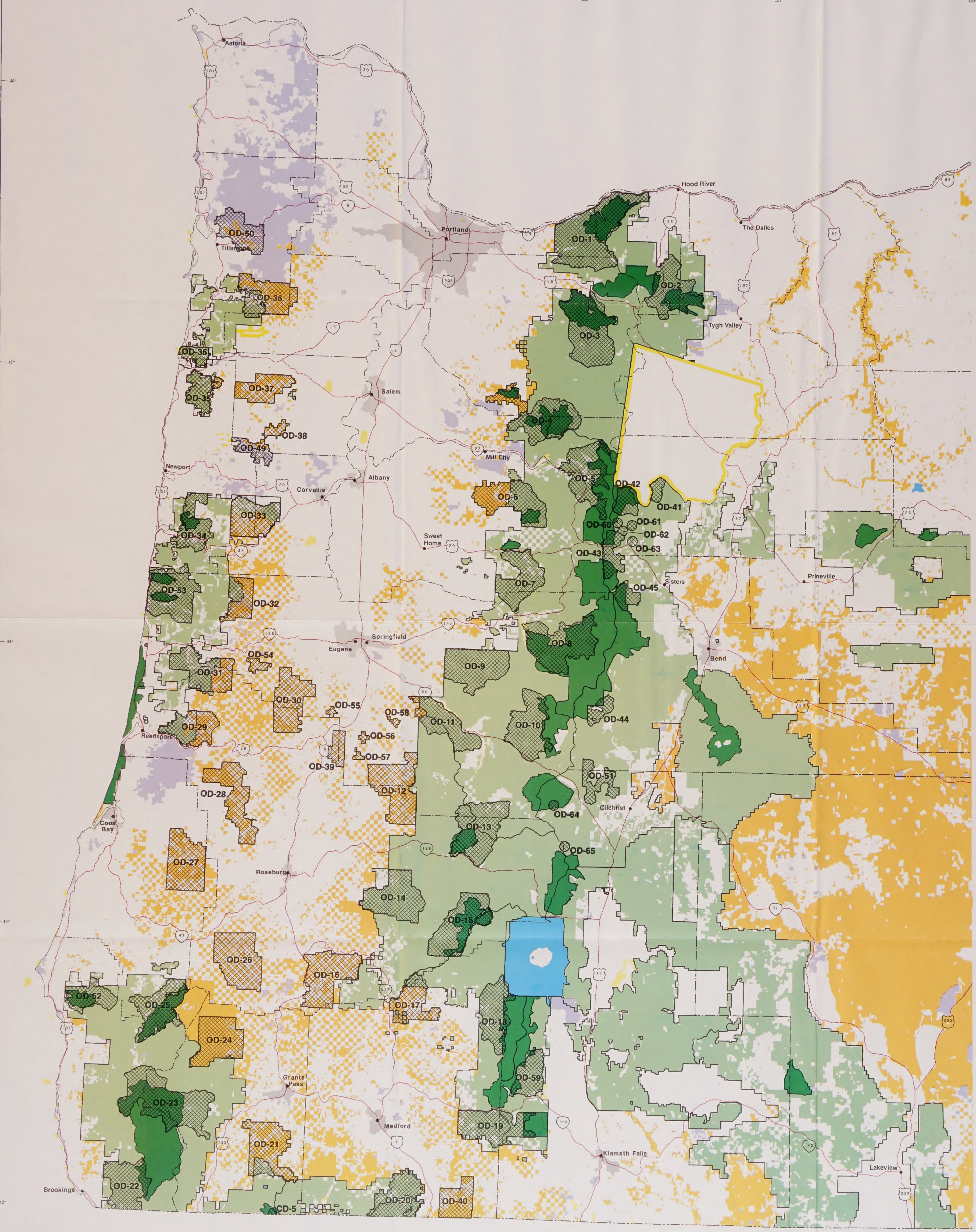
Designated Conservation Areas (DCAs)

Northern Spotted Owl
DRAFT
Recovery Plan

State of Oregon

Approximate Scale 1:700,000
1992



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- Indian Reservations

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United States Department of the Interior

Map Base: BLM State Map, 1982. Land Status Revised in 1985.

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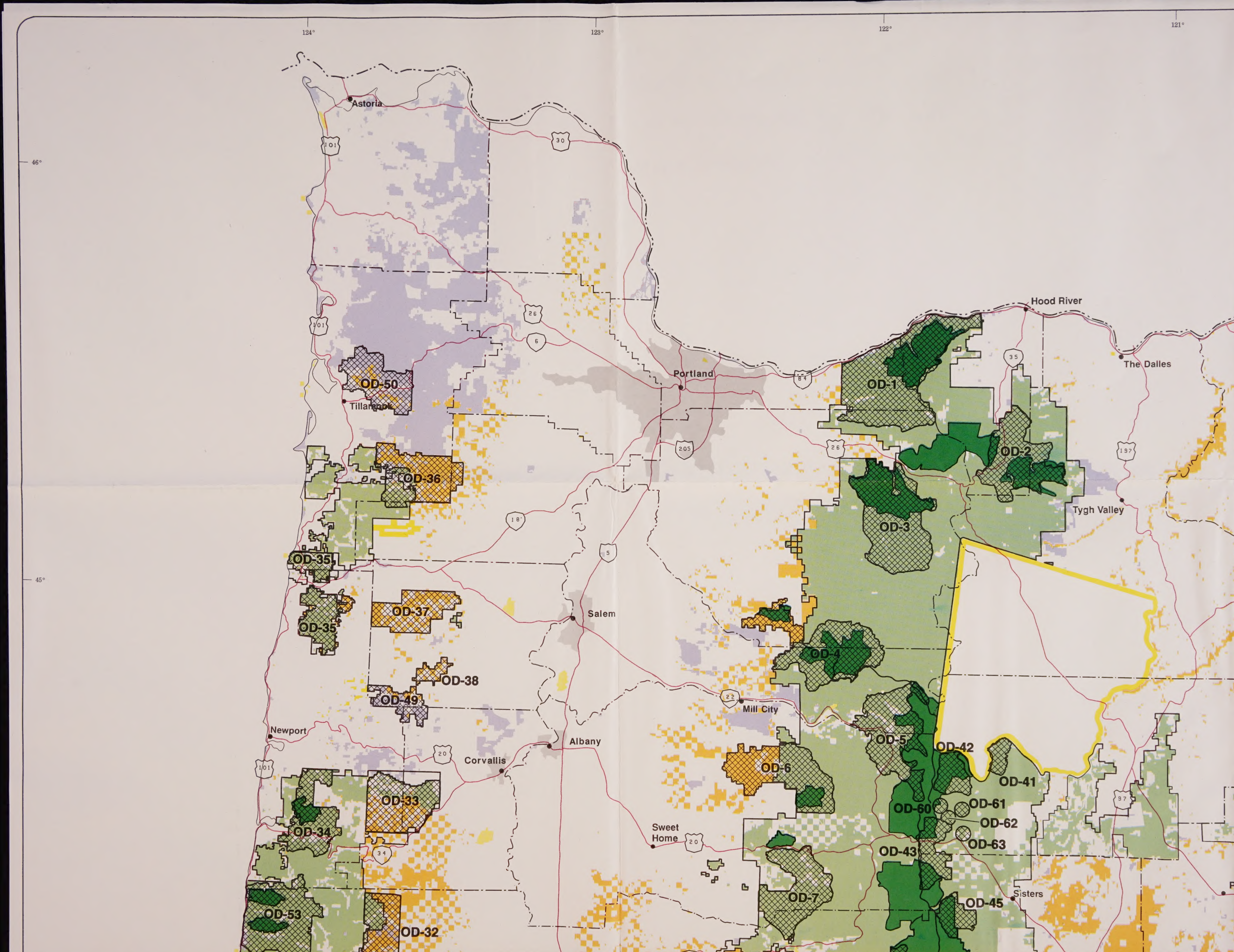

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46°
45°
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Portland
Hood River
The Dalles
Tygh Valley
Salem
Mill City
Newport
Albany
Corvallis
Sweet Home
Sisters
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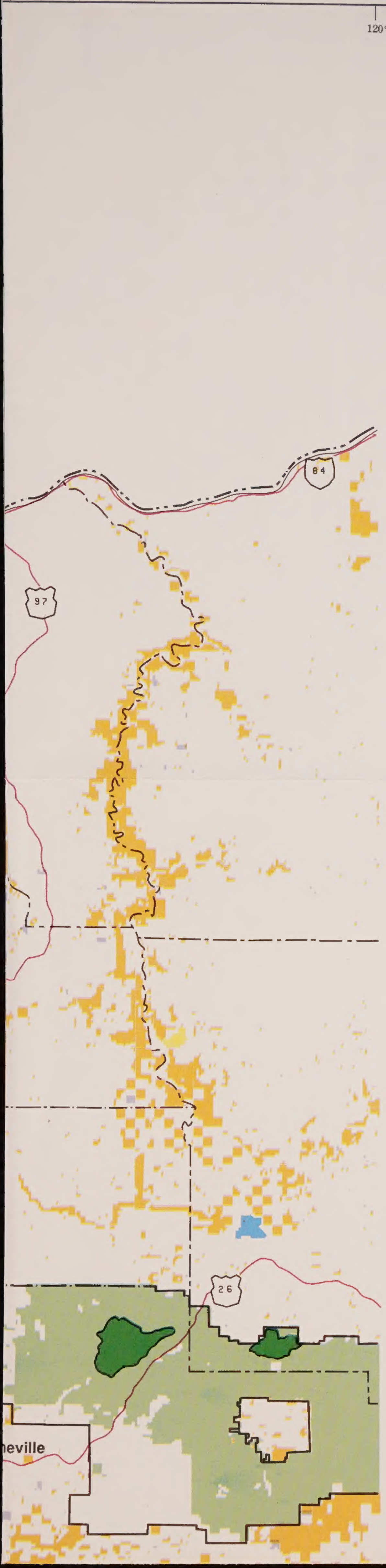
OD-63



Designated Conservation Areas (DCAs)

Northern Spotted Owl
DRAFT
Recovery Plan

State of Oregon

Approximate Scale 1:700,000
1992

LEGEND

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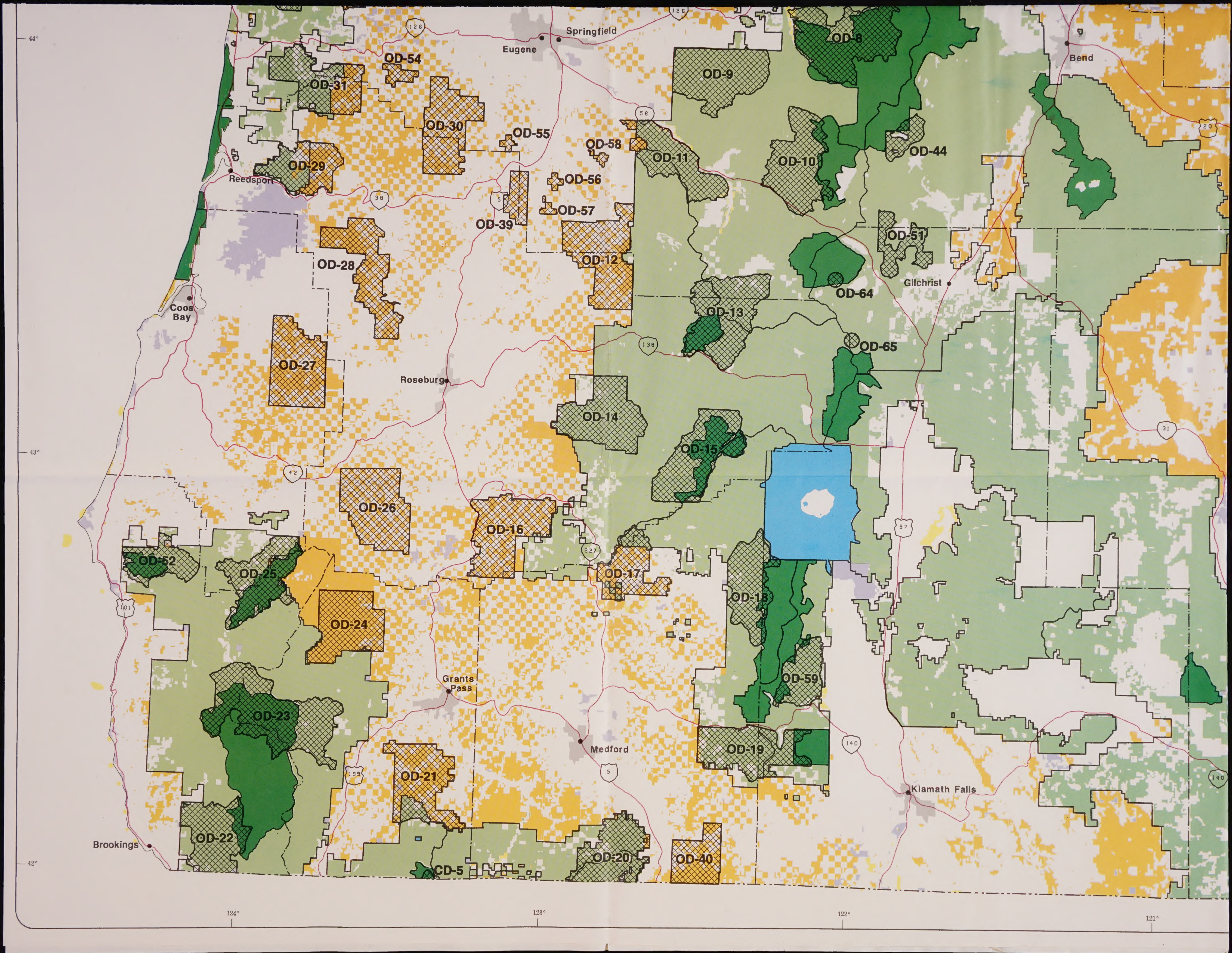
- County Boundary
- 12 Roads



Springfield
Eugene
Bend
Reedsport
Coos Bay
Roseburg
Gilchrist
Grants Pass
Medford
Klamath Falls
Brookings
OD-8
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OD-57
OD-58
OD-59
OD-64
OD-65
CD-5
44°
43°
42°
124°
123°
122°
121°

OD-28 Designated Conservation Areas managed for northern spotted owl recovery.

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NOTE
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United States Department of the Interior

Map Base: BLM State Map, 1982. Land Status Revised in 1985.

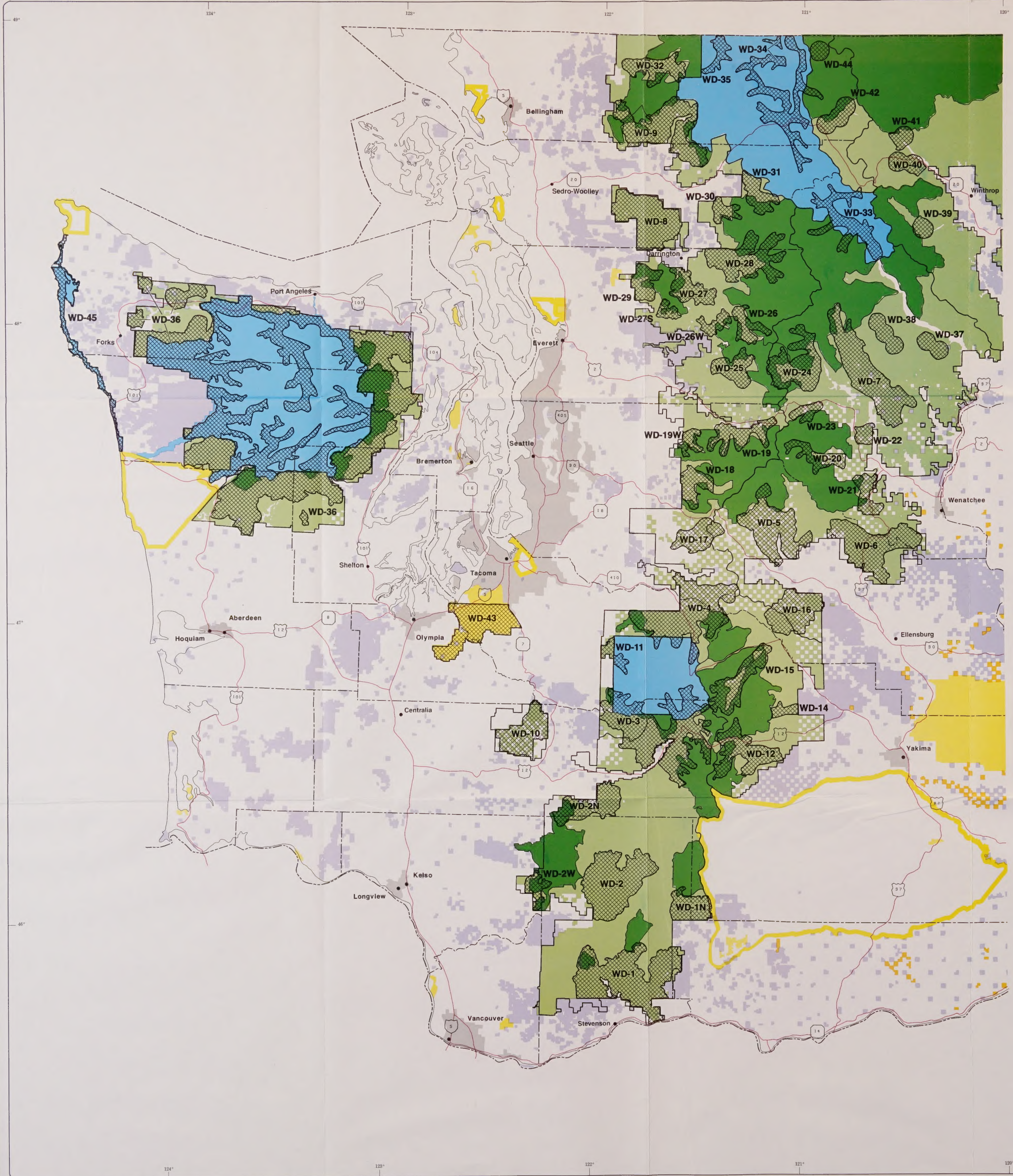
☆ U.S. GOVERNMENT PRINTING OFFICE: 1991—691-303/42,200 REGION 10

Designated Conservation Areas (DCAs)

Northern Spotted Owl
DRAFT
Recovery Plan

State of Washington

Approximate Scale 1:700,000
1992



LEGEND

- National Forest (not reserved)
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- Bureau of Land Management
- National Park Service
- Other Federal Lands
- State Lands
- Indian Reservations
- Forest Boundary
- Reserved Lands Boundary
- County Boundary
- State Boundary
- Roads

WD-28 Designated Conservation Areas managed for northern spotted owl recovery.

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NOTE
Schematic map; not to scale; intended for display purposes only.

United States Department of the Interior

Map Base: Washington State Department of Natural Resources, 1988.

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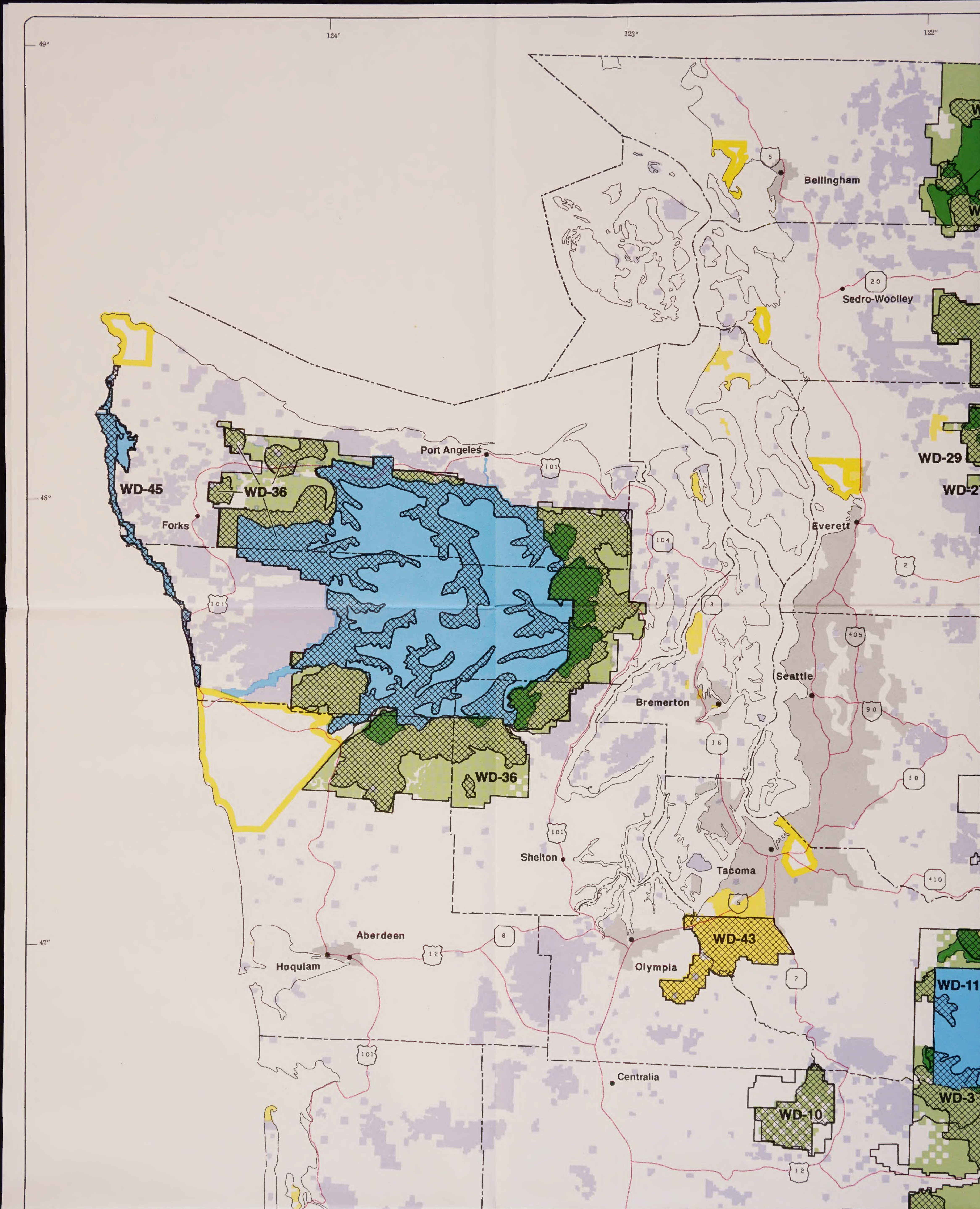
49°
124°
123°
122°
48°
47°
Bellingham
Sedro-Woolley
Port Angeles
WD-45
WD-36
Forks
Everett
WD-29
Seattle
Bremerton
WD-36
Shelton
Tacoma
WD-43
Olympia
Aberdeen
Hoquiam
Centralia
WD-10
WD-11
WD-3
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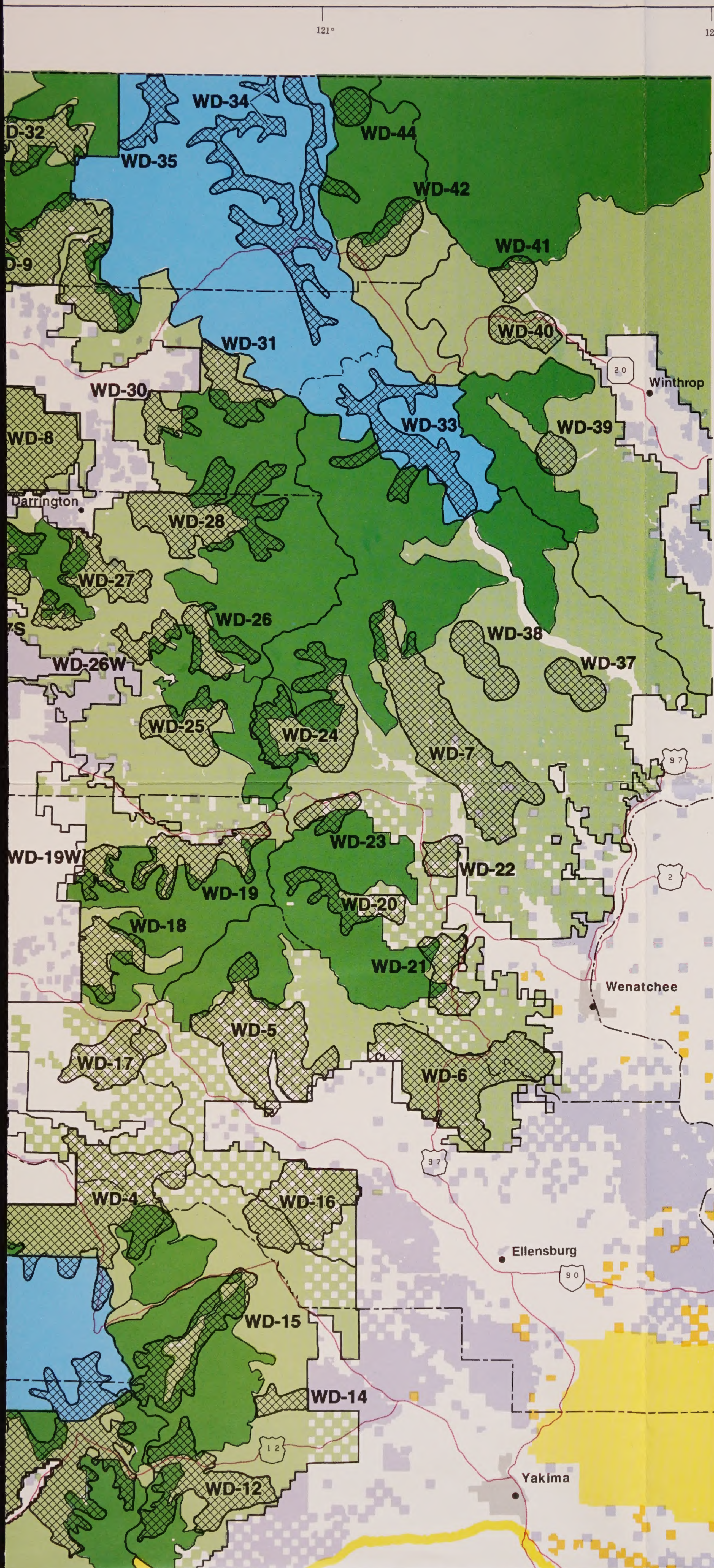
12



Designated Conservation Areas (DCAs)

Northern Spotted Owl *DRAFT* Recovery Plan

State of Washington

Approximate Scale 1:700,000
1992

LEGEND

- National Forest (not reserved)
- Wilderness, National Monument, National Recreation Area
- Bureau of Land Management
- National Park Service
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WD-28 Designated Conservation Areas managed for northern spotted owl recovery.

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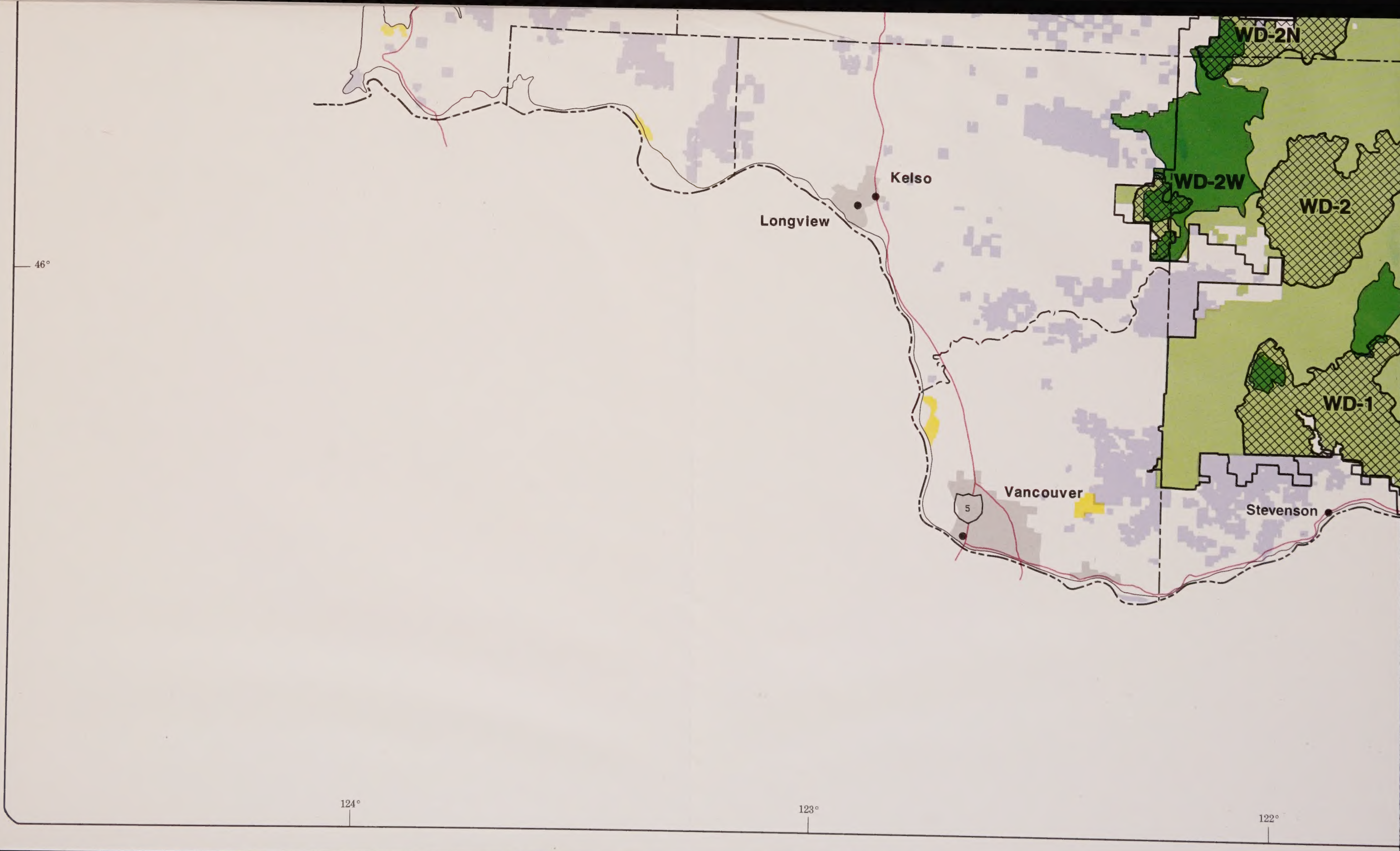
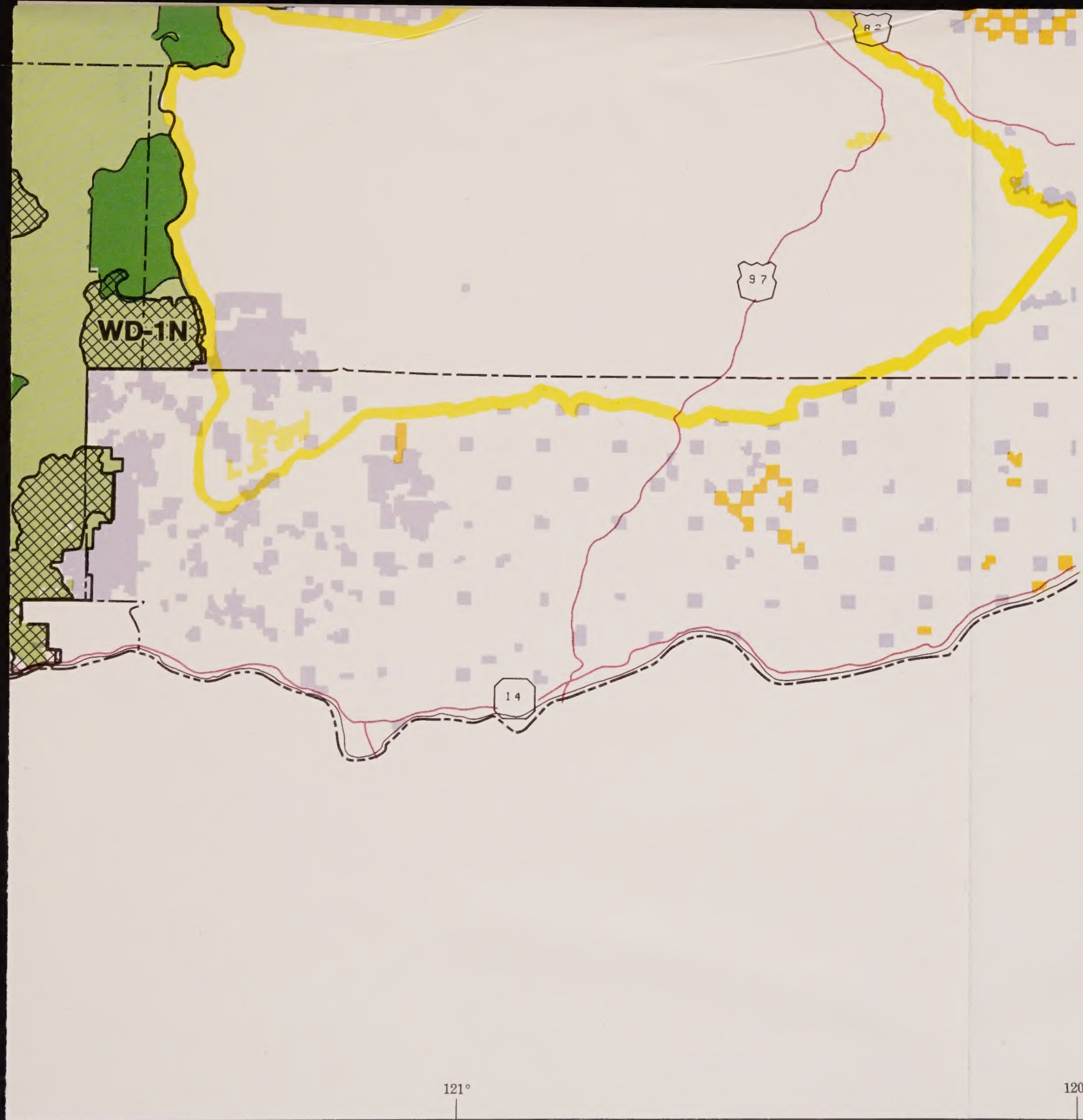


WD-2N
WD-2W
WD-2
WD-1
Kelso
Longview
Vancouver
5
Stevenson
46°
124°
123°
122°



NOTE
Schematic map; not to scale;
intended for display purposes only.

United States Department of the Interior

Map Base: Washington State Department of Natural Resources, 1988.

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